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ABSTRACT

Cognitive and non-cognitive influences on the mathematical learning of children attending four community schools in different provinces of Papua New Guinea and an international primary school in Lae were investigated. Altogether, 446 pupils, most in grades 2, 4, or 6, were given pencil-and-paper group tests; 253 pupils were also given individual tests of visual memory and memory space. Forty-four boys were selected for intensive study and given a battery of individual tests, including equipment-based tests of mathematical problem solving; conservation of number, length, and quantity; and spatial abilities. Memory span measures were also obtained. Whenever necessary, individual testing was carried out in the child's vernacular. Each of the 44 boys was interviewed, with an attempt made to glean his attitude toward school mathematics and influences affecting the ways he learned it. Analysis revealed that the patterns of abilities of National (native Papua New Guinean students) and Expatriate (students of the Lae International Primary School) children were similar. However, Expatriate children clearly outperformed National children on pencil-and-paper group tests. Evidence is presented to show that the difference in performance level is largely a function of language and home background factors. Instruments are included in the appendixes. (Author/MNS)

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INDIGENOUS MATHEMATICS PROJECT

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INFLUENCES OF MATHEMATICAL LEARNING IN PAPUA NEW GUINEA – SOME CROSSCULTURAL PERSPECTIVES

M.A. (Ken) Clements
Glen Lean

Working Paper 17
May 1981

THE INDIGENOUS MATHEMATICS PROJECT

This series of working papers and research reports has been published to provide a comprehensive source of documentation on research and development efforts associated with the Indigenous Mathematics Project. The Project was established in 1977 by the Government of Papua New Guinea to investigate various aspects of traditional mathematics development. During the first phase (1977–79) of the five year program, basic research in crosscultural cognitive development was carried out and indigenous counting, classification and measurement systems used throughout the country were documented. During the second phase of the project (jointly funded by the Department of Education and UNESCO), pilot instructional materials were developed and trialled. The intent was to assess the feasibility of utilizing complementary aspects of indigenous and Western mathematics as a basis for developing culturally relevant student materials, instructional aids and teachers' guides which reflect the practical constraints of the community school environment. The results of IMP work are intended to inform future curriculum development in an effort to provide more appropriate instructional materials and learning aids for Community Schools throughout Papua New Guinea.

Series Editor: Randall Souviney
Managing Editor: Jacquie Wathen

INFLUENCES ON MATHEMATICAL LEARNING IN PAPUA NEW GUINEA
- SOME CROSS-CULTURAL PERSPECTIVES

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M.A. (Ken) Clements

G.A. Lean

INFLUENCES ON MATHEMATICAL LEARNING IN PAPUA NEW GUINEA: SOME CROSS-CULTURAL PERSPECTIVES

ABSTRACT

An investigation into cognitive and non-cognitive influences on the mathematical learning of children attending four Community Schools in different provinces of Papua New Guinea, and an international primary school in Lae, is described. Altogether, 446 pupils, mostly in grades 2,4, or 6 at the five schools were given pencil-and-paper group tests; 253 of the 446 pupils were also given individual tests of visual memory and memory space. Forty-four boys were selected for intensive study and given a battery of individual tests, including equipment-based tests of mathematical problem-solving, conservation of number, length, and quantity, and spatial abilities; measures of visual sequential and simultaneous memory spans, and forwards and backwards auditory memory spans, were obtained. Whenever necessary, individual testing was carried out in the vernacular of the child. Each of the 44 boys was interviewed, and an attempt was made to glean from each boy his attitude towards school mathematics and the influences which affected the ways he learnt it.

Analysis revealed that the patterns of abilities of National and Expatriate children were similar. However, Expatriate children clearly outperformed National children on pencil-and-paper group tests. Evidence is presented to show that the difference in level of performance on group tests is largely a function of language and home background factors.

1. INTRODUCTION

In a recent report R.E. Roberts, the Senior Curriculum Officer (Mathematics) of the Papua New Guinea Department of Education, and V. Kada, a research officer in the Department of Education, stated that levels of achievement in primary mathematics in PNG. are failing and have, perhaps, fallen to an unacceptably low level, a level at which further education and trade and professional training programmes cannot operate effectively (Roberts & Kada, 1979, p.174). They also produced evidence to show that many Community School teachers do not have a good understanding of the mathematics they are expected to teach, and claimed that this has contributed to a situation in which most mathematics lessons are of a stereotyped nature, in which high order questions are not asked by the teachers or the children, and children work at the pace of their teachers rather than teachers at the pace of their children (p.187).

The evidence and arguments presented by Roberts and Kada are complemented by recent developmental studies in Papua New Guinea. Shea (1978), in summarizing these studies, states that on Piagetian conservation tests Papua New Guineans generally perform less well than certain selected Western European groups. According to Shea,

> generally speaking it seems that with the conservation skill which appears earliest, that of Number, there seems to be about a 3-year delay for PNG students. This delay seems to lengthen gradually with the more difficult tasks, until it is approximately 6 for the Volume and Time conservation tasks (Shea, 1978 p.91).

More recently, Jones (1980) has reported an investigation in which Engineering students at the PNG University of Technology (Lae) performed at roughly the same level as ninth-grade pupils in an English grammar school on ratio and proportion tasks.

Given the difficulties Papua New Guinean children and teachers are experiencing with mathematics, and the findings of developmental psychologists, the task of defining an appropriate mathematics curriculum for Community Schools becomes especially unenviable, and difficult. On the one hand some politicans and higher educational authorities expect pupils completing their primary schooling to be as mathematically competent as corresponding children in more developed countries; on the other hand there is the danger that children will be presented with mathematical material which they are not ready to learn, from the point of view of cognitive development. There are also the difficulties arising from the fact that

English is the language of instruction. According to R.E. Roberts, there is evidence that the problems attendant on the use of English as a medium of education are growing, and 'it seems that there are some schools where English is being taught very, very badly' (Roberts, 1978, p.209).

Clearly, then, there are many unsolved teaching and learning problems associated with the recently implemented MaCS (Mathematics for Community Schools) course (Roberts, 1978, pp.208-216). Thus, there is a need for research which will inform future mathematical curriculum developers of those abilities which are, and are not, well developed in P.N.G. children, and which will clarify the implications of such research for those responsible for modifying the mathematics course for Community Schools. The studies of David Lancy (1978) and Alan Bishop (1978(a)), in which small samples of children were given batteries of individual tests, are, in the view of the present writers, excellent examples of the type of research which is needed.

1.1 BISHOP'S CONJECTURES

It was Bishop's work in Papua New Guinea in 1977 which was the genesis of the study reported here. Bishop (1978(a), 1979) intensively investigated the spatial abilities of a small sample of twelve students, who came from three provinces only. As a result of his research he put forward the following researchable hypotheses :

1. Pictorial representational conventions are teachable.
2. Training students in drawing and sketching techniques improves their ability to read and interpret other people's diagrams.
3. Manipulative work with concrete apparatus aids and improves students' spatial abilities.
4. There are significant variations in the capacity of local languages to express spatial ideas.
5. The variation in quality of local spatial vocabulary accompanies visualizing skill.
6. Orientation and mapping skills are more developed in PNG students than other types of spatial abilities.
7. Memory tasks are performed by PNG students with little or no verbal mediation.
8. Within-group variability in spatial ability is greater than between-group variability.
9. Less acculturated students have better visual memories than students who are more acculturated.

10. Students coming from areas where the local language contains no (easy) conditional mood will tend towards a greater use of visual memory and ikonic processing.

11. Teaching strategies emphasizing 'understanding' will be less successful in the short term than those which emphasize 'memory'.

12. Symbolic and hierarchical processing and coding is teachable (Bishop, 1978(a), pp.36-40).

Implicit in these conjectures is a belief that Papua New Guinean students tend to have good memories but, relative to Western students, find it difficult to grasp abstract principles. In commenting on his eleventh researchable hypothesis (above), Bishop wrote:

> From my perspective the whole educational development exercise is enmeshed in the long slow process of cultural adaptation. Strategies which are designed to foster understanding, the 'meaning' of general principles, the subtle use of example and counter-example to extend or test out generalizations and hypotheses, etc., are so dependent on the supporting framework of 'Western' ideals, philosophies and societal values that they are literally meaningless within the PNG culture as it is at present (Bishop, 1978(a), p.39).

Bishop added that since there is little evidence that teaching strategies are potent change agents it would seem to be more productive to concentrate efforts on devising teaching strategies which rely on and foster a strength, rather than merely adopting current Western methods. Lancy (1978, p.133) has argued, however, that Community Schools 'which provide a variety of media which pupils act upon' accelerate the transition to symbolic thought. Further, on the basis of data showing that National children, attending an international school in Port Moresby, performed as well as Expatriate children at the same school on a variety of individual cognitive tests, he has claimed that, given a thoroughly Western living environment and a higher quality school environment, Papua New Guinean children should perform the same as Western children (Lancy, 1978, p.136).

Bishop, it would seem, is putting the view that, whether one likes it or not, it is necessary for curriculum planners and teachers to recognize that Papua New Guineans are, for the most part, at a 'prelogical' stage, and, if he is right this would be especially true of Community School children. Levy-Bruhl (1966, quoted in Cole and Scribner, 1974) has argued in a similar way. Lancy, on the other hand, has argued more along the lines of Cole and Scribner (1974, p.193), that 'we are unlikely to find cultural differences in

basic component cognitive processes', and that 'there is no evidence in any line of investigation that we have reviewed that any cultural group wholly lacks a basic process such as abstraction, or inferential reasoning or categorization'. Data supporting this latter point of view, but based on studies conducted outside Papua New Guinea, are presented by Stevenson et al. (1978), Sharp et al. (1979), and Kagan et al. (1979).

1.2 THE PROPOSED STUDY

As previously stated, the investigation which is described in the present paper was undertaken as a follow-up study to Bishop's work in Papua New Guinea. Like Bishop, the spatial abilities and mathematical performances of Papua New Guineans would be the main thrust of the study but, unlike Bishop, the study would involve Community School children rather than tertiary students. By intensive investigation of younger children, in different grades, in different schools, in different provinces, it was expected that patterns of developing abilities and mathematical performances of children would be revealed. Bishop's results could then be examined in the light of these patterns. It should be noted, too, that during the time this investigation was being carried out we were also involved in a large-scale project concerned with identifying the extent to which Engineering students at the PNG University of Technology (Unitech) used spatial abilities and visual imagery when processing mathematical information (Lean and Clements, 1981).

With respect to the study involving community school children a proposal was submitted to Dr Randall Souviney, Director of the Indigenous Mathematics Project (I.M.P.), with a request for funds to supplement those provided by the Mathematics Education Centre (M.E.C.) at Unitech. The project thus became a joint I.M.P./M.E.C. venture. As a result of this collaboration the original proposal was modified in a number of ways so that there would be some overlap between this project and a materials development project which was being conducted by the I.M.P. In the final form of our project it was proposed to investigate a variety of both spatial and mathematical abilities of a sample of Community School children. Specifically, it was decided to investigate, using an individual interview technique, six children, ranging from grades 2 to 6, in each of five schools: Wonenara (Eastern Highlands), Kero (Southern Highlands), Kabagap (East New Britain), Andra (Manus), and Lae International Primary School. For certain tasks, where additional data would be judged useful, the sample would be enlarged.

The areas of investigation would include visual memory, the understanding of spatial conventions, the co-ordination of perspectives, simple mathematical problems, conservation and estimation of length, area, and quantity, and the possible effects of school and environment on performance on various tasks. As in the Bishop study, only male subjects would be included in the sample whose abilities and performances would be intensively investigated.

The study was carried out during the period March-July 1980, and involved four field trips, of approximately one week each, to the sites outside Lae.

This report discusses the schools within their communities, describes the samples and the tasks, provides a summary and an analysis of the data, and a discussion of their implications, both for mathematical education in Papua New Guinea and, more generally, for cross-cultural educational research.

2. THE MAIN STUDY

2.1 THE SITES

The four Community Schools included in the study were chosen to provide contrasts in environment and the students' degree of acculturation. Two of the schools, Andra and Kero, were involved in the I.M.P. research project. Details of the schools and their locations are given below together with a list of the experimenters working at each site.

Wonenara

Wonenara lies in the south-east of the Eastern Highlands Province. It has an airstrip, a government station and a Community School. The Community School opened at the beginning of 1979 and now accepts children at grades 1 and 2; there is a headmaster and one teacher and 120 students. It is not the first school in the area: a mission primary school operated there about fifteen years ago. The people of this area belong to the Anga or Kukukuku cultural and linguistic group (Lloyd, 1973); the largest tribe, called Baruya (as is their language), is situated south of Wonenara. Two research workers have studied the Baruya language at Yanyi Village, under the auspices of the Summer Institute of Linguistics (S.I.L.), periodically since 1960 (Lloyd and Healey, 1970; Lloyd, 1969 and 1973), although the area was not regarded by the colonial administration as having been 'pacified' until 1966. The culture of the Baruya has been extensively studied by M. Godelier of the University of Paris (Godelier, 1977, 1979).

The research was carried out at Wiyava, about an hour and a half's walk from Wonenara, at the home of the two S.I.L. linguists, R. and J. Lloyd. Of the six male subjects chosen, three attended grade 2 at Wonenara Community School; the other three, who were co-initiates (Lloyd, 1969) of these and hence approximately the same age, had not attended school. Each of the six subjects was aged from thirteen to fifteen years, and the three school subjects spent about three hours each day walking to and from school.

In addition to the authors, the research team included Dr F. Ausburn of Monash University, who recorded much of the project on film, Dr L. Ausburn of Swinburne College of Advanced Education in Melbourne, and Mr Atawe Koigiri, a National tutor in Mathematics at the University of Technology. Mr Koigiri, who comes originally from Wiyava, acted as our translator. Additional assistance with language was also provided by R. and J. Lloyd.

Kero

Kero Community School is situated about two kilometres from Ialibu in the Southern Highlands Province. Mt Giluwe, the second highest mountain in PNG, can be seen to the north of the school, and Mt Ialibu, more than 3500 metres high, lies to the south. The Ialibu sub-province came under European influence about twenty-five years ago and thus far economic development has been slow. Ialibu people prefer to retain their traditional village life-style, the women tending gardens and raising pigs and the men building houses and clearing gardens. There is not much involvement in cash economy activities, although locals often buy and sell with enthusiasm at Saturday morning markets.

The Community School was opened in 1966 and was the first school to be established in the area. The first school buildings were built by parents, but later additional classrooms were constructed by the local council, with financial support being provided by the colonial Administration. In 1980 the school had a headmaster, seven teachers, and approximately 300 pupils in grades 1 to 6. Many of the pupils have a one to two hours' walk to school each schoolday. Such pupils need to leave their villages at 6 a.m.; often they do not return home until well after 5 p.m.

At the time they enter school most pupils speak their tok ples, (local language), Imbonggu, only, although a few speak tok pisin ('Pidgin'), also. English is gradually acquired at school. By grade 4 most pupils speak tok ples and tok pisin fluently, and have a fair grasp of English. In

the individual testing for the present study, tok ples was used for grade 2 children, tok pisin or tok ples for grade 4 children, and English (and, if necessary, tok pisin or tok ples) for grade 6 children.

At Kero the research team consisted of the authors and Mr Henry Korim, the Associate Director of the M.E.C. Wagena, a local villager who spoke English, tok pisin and tok ples, was trained to act as our interpreter, and gave excellent service in this capacity. The research team stayed in the house occupied by Mr Andrew Piason, the sixty-grade teacher at the Community School, and all interviews were conducted in this house.

Kabagap

The village of Tinganalom is situated 28 miles from Rabaul, East New Britain Province, five miles off the Kokopo road. European traders, planters and missionaries purchased land at Herbertshohe (now Kokopo) and Vunapope, about 8 miles away, in the early 1880s and in 1900 the legendary 'Queen' Emma Kolbe owned large plantations in the area (Gash and Whittaker, 1975). The German colonial administration was succeeded, at the outbreak of the First World War, by an Australian administration (Rowley, 1958) which continued, despite an hiatus during the Second World War when the Gazelle Peninsula was under Japanese occupation, until Independence in 1975.

Mission schools have operated in the area for many years. In the 1960s the Australian administration established Kabagap Primary (now Community) School at Tinganalom and it serves this and several other nearby villages. The language of the area is a dialect of Kuanua, the main language of the Gazelle Peninsula. This is the first language of the children attending Kabagap; the second language is usually tok pisin and the third, taught at the school, is English.

The villagers of Tinganalom and the surrounding area are generally prosperous, deriving their income from selling copra and cocoa, or running small businesses. Some of the children at Kabagap have fathers who were educated at school; many have brothers and sisters who have gone to high school and in some cases, tertiary institutions.

The research was conducted at the school by the authors who stayed in a village not far from the school. One of the authors (Lean), who speaks Kuanua fluently, acted as interpreter. In the individual testing tok ples was used for grade 2 children, tok pisin or tok ples for grade 4 children, and English (and if necessary, tok pisin or tok ples) for grade 6 children.

Andra

Andra Island is situated off the north coast of Manus Island, a canoe journey of an hour or two from Lorengau, the capital of the Manus Province. The island is about 600m long and 200m across and has a resident population of about 400 people. Many young men leave the island to seek employment elsewhere.

The Admiralty Islands, of which Manus is the largest, was part of German New Guinea; an administrative station had been established in Lorengau in 1911 and was taken over by the Australian administration during the First World War. During the Second World War Manus was the site of American naval and air bases. The extent of European contact and its effects on Manus life in 1928 were described in some detail by Margaret Mead in her book New Lives for Old (Mead, 1956).

A Catholic Mission School was established on Andra in the 1960s and in the early 1970s the people of Andra contributed money and helped build new school buildings on the present site. The school now has about 100 pupils in grades 1, 4, 6 who are taught by a headmaster and one other teacher. At the time they begin school most children usually speak two languages, their first language, Andra, and the second, tok pisin. English is acquired at school. The school is assisted in many ways by the people of the island, and appears to be regarded as an important part of the community. A number of families own canoes powered by outboard motors, and these are used to travel to Lorengau, to market, and neighbouring islands. Seafood is plentiful and is the staple food for the islanders. Fish is bartered at market and sold at Lorengau as well. Many children have their own small canoes and spend their out-of-school daylight hours fishing and swimming.

The research team at Andra consisted of the authors and Associate Professor P.L. Jones, head of the Mathematics Department at the University of Technology. In the individual testing tok pisin was used for grade 1 and grade 4 children and English (and, if necessary, tok pisin) for grade 6 children.

2.2 THE SAMPLE

The Community School sample for the face-to-face interview study comprised six subjects from each of the four sites outside Lae. Where possible, the subjects chosen at a particular site were from grades 2, 4 and 6, two subjects from each grade. There were two exceptions to this.

The first was at Wonenara where the school only went up to grade 2; the subjects there were three grade 2 students and three of their peers who had not attended school. The second was at Andra where there was no grade 2 class and grade 1 students were used instead. All the subjects were male and, at any particular site, spoke the same language. At all sites except Wonenara, two subjects, who were approximately the same age, were selected from each of the three grades on the basis of their results on the Primary Mathematics Achievement Test (PMAT) prepared by the I.M.P. (see The Tasks). For each pair of students at a particular grade level, one was in the upper third, the other in the lower third, of the PMAT results.

In Lae, at the International Primary School, where more time was available for the investigation, a larger number of subjects was tested and the sample included both National and non-National children. Twenty subjects were selected for intensive study, seven from grade 2, six from grade 4, two from grade 5, and five from grade 6. Selection was based on their results on class mathematics tests, approximately equal numbers being chosen from the upper third and the lower third of the class results.

As an important aim of the present study was to generate ideas (as was the case in Bishop's original study), the sample was deliberately kept small so that each subject could be investigated in depth. In cases where it was thought useful to use formal statistical procedures to test hypotheses, an expanded sample was used; it will be indicated in the later parts of the paper when this was the case. The smaller sample, consisting of forty-four subjects (eighteen in the Kero, Kabagap and Andra Community Schools, six at Wonenara, and twenty at the International Primary School) will sometimes be referred to as the 'interview' sample. Occasionally the same expression will be used to refer to thirty-eight of these subjects - the six Wonenara subjects not being considered.

3. THE TASKS

The individually administered tasks can be conveniently subsumed under twelve headings:

i) visual memory (2-D),
ii) aural digit span,
iii) visual memory (3-D),
iv) memory space,

v) a 'mathematics' test which included conservation and estimation tasks,

vi) a 'fitting shapes' task,

vii) Deregowski models from diagrams,

viii) Deregowski models from photographs,

ix) Hughes' perspective task,

x) co-ordination of perspectives task,

xi) memory-for-designs, and

xii) interview about such matters as family background, out-of-school activities and interests, and attitudes to mathematics.

In addition to these individually administered tasks, three pencil-and-paper group tests were used: i) the Primary Mathematics Achievement Test, prepared by Dr Randall Souviney (1980), Director of the Indigenous Mathematics Project; ii) a modified version of the Monash Assessment of Mathematical Performance, devised by Clements (1980), and iii) a Mathematics Language Test, devised by Jones (1981a). Five main categories of tasks can be identified:

1. Memory Tasks
   (a) visual memory (2-D)
   (b) aural digit span
   (c) memory space;
   (d) memory-for-design ;
   (e) visual memory (3-D).

2. The Mathematics Test
   (a) practical problems involving simple arithmetical calculations
   (b) conservation of number, length, and substance
   (c) estimation of number, length, and substance

3. Spatial Tasks
   (a) 'fitting shapes'
   (b) Deregowski models (from drawings and photographs)
   (c) perspective tasks (the Hughes' tasks and co-ordination of perspectives)

4. The Group Tests
   (a) Primary Mathematics Achievement Test (PMAT)
   (b) Monash Assessment of Mathematical Performance (MAMP)
   (c) Mathematical Language Test

5. Interview

It is within these five categories that the tasks will be described in detail and, subsequently, results presented and discussed.

At all sites except Andra (where all subjects understood English or tok pisin), young subjects who were not familiar with English were assisted by an interpreter, who translated the instructions and the subjects' responses for individual tasks. To check that the conceptual content of the questions or instructions were being adequately translated a 'back-translation' procedure (Brislin, 1970) was carried out in each of the vernaculars (except Andra) prior to the beginning of testing. The rest of the subjects were tested either in tok pisin or in English. English was used only when it was felt that the subject was sufficiently fluent in it not to be disadvantaged by its use. Each subject was tested in a private room, usually sitting at a table across from the experimenter. After a sequence of tasks had been performed the subject was allowed to rest before continuing. The mean testing time per subject (not including time for group tests) was about four hours. The experimenter kept a detailed record sheet noting responses and behaviour for each subject. At all times the subjects tried their hardest and co-operated fully. They seemed to enjoy participating in the study.

3.1 MEMORY TASKS

A recent seminal paper by Torgesen et al. (1978) reported data which suggested strongly that for memory tasks involving presentation of digits, task structure (simultaneous versus sequential presentation of digits) was a more powerful variable in determining individual differences than modality

of presentation (visual versus auditory). In another recent study, Swanson (1978) concluded that normal readers recall non-familiar random shapes better if they have learnt verbal labels for the shapes, but 'learning disabled' readers who have learnt the same verbal labels do not improve their ability to recall the same shapes. These studies would appear to be relevant to Bishop's conjectures concerning the memories of Papua New Guineans. Bishop (1978(a), 1979), following Kearins (1976), included a series of visual memory tasks, but no auditory memory tasks in his study; also his tasks involved the simultaneous, but not sequential, presentation of stimuli. Further, his tasks involved the memorization of twelve objects, or pictures, presented as 3 x 4 arrays; linear arrangements were not included among Bishop's tasks. Given the findings of Torgeson et al. and Swanson, we decided that a more comprehensive series of memory tasks were needed in order to test Bishop's conjectures concerning memory.

Visual Memory Tasks

Each subject in the smaller sample was given eleven visual memory tasks; in addition, a larger sample, containing 253 children, was used for three of the tasks (see Tasks, 3, 7, 8, below) in order that theories of Bishop, Torgeson et al., Swanson, and the present writers might be fully investigated.

The first eight tasks had a common form of administration: on a rectangular cardboard matrix, divided into a given number of squares, a random array of objects, (numbers, symbols) was placed in front of the subject. The subject was told he must look carefully at the array for a given time and remember where the objects were placed. After the given amount of time had elapsed the objects were removed from the matrix and given to the subject who was asked to replace them in their correct positions. No time limit was set for the replacement of the objects. The size of matrix and the type of object used varied as follows:

Task 1. A 2 x 3 (20cm x 30 cm) matrix with an array of six small objects (leaf, stone, betel nut, etc.) which were familiar to the subject.

Task 2. A 2 x 3 matrix with an array of six unfamiliar objects.

Task 3. A 3 x 4 (30cm x 40cm) matrix with an array of twelve familiar objects.

Task 4. A 3 x 4 matrix with an array of twelve unfamiliar objects.

Task 5. A 2 x 3 matrix with an array of six numerals.

Task 6. A 2 x 3 matrix with an array of six 'nonsense' symbols (Greek letters, etc).

Task 7. A 3 x 4 matrix with an array of twelve numerals (the positive integers from 1 to 12).

Task 8. A 3 x 4 matrix with an array of twelve 'nonsense' symbols.

The ninth task in the visual memory sequence, termed 'simultaneous linear visual digit span', involved the subject being exposed to linear arrays of numerals starting with a 1 x 3 array and proceeding to higher order arrays if successful. In each case the subject was instructed to look carefully at the array and remember where each numeral was placed. The whole array was revealed to him for ten seconds and then covered. He was then given a blank matrix and cards with integers 1 to 10 on them and asked to choose the correct numerals and place them on the blank matrix in their correct position. No upper limit was put on the replacement time. If the subject was successful, the next, higher-order, array of numerals was presented. The score obtained on this task was the order of the highest linear array of numerals which were all correctly replaced.

For Task 10, the subject was shown a blank 2 x 3 matrix and was instructed that the experimenter would tell him what numerals occupied each square of the matrix (but no numerals would be shown). The experimenter indicated the six numbers and their positions, with a pause of one second being allowed between each indication of a position. The subject was asked to name each number and state its correct position by pointing to the appropriate blank square.

Task 11, the 'sequential linear digit span', was identical to Task 9 except that for each linear array of digits the numerals were revealed sequentially, one at a time, with one second exposure for each.

For further details of the 2-D visual memory tasks, see the 'Results Sheet' in Appendix A.

Auditory - Oral Digit Span

There were two parts to this task, digits forward and digits backward. In the first, digits were spoken by the experimenter at the rate of one per second, starting with a three-digit series and proceeding to higher-order series if the subject successfully repeated a series. Recall was taken orally. A similar procedure was followed for the second task except that the subject was required to repeat the series backwards.

For both tasks a subject was given a second chance if an error was made, a new series of the same length being given. The score obtained by a subject for a task was the length of the longest series for which he gave a correct response.

Memory Space

In order to qualify as a measure of working memory, a task must meet the following requirements: (1) it must require some transformation of the input to ensure that it truly measures 'working' memory and not simply 'reproductive' or 'short-term' memory; (2) the task must be solvable by only one strategy or at most by a family of equivalently complex strategies to ensure that whatever developmental trends are obtained cannot be ascribed to increasing strategic sophistication; (3) the task must include a substantial training component to ensure that developmental differences cannot be ascribed to differences in the availability of the underlying strategies or operations; (4) the task must be constructed so that the experimenter can gradually increment the number of items that must be held in storage while the strategy is executed to determine the subject's highest level; (5) last, the task must employ items not amenable to any higher-order coding of relevance to the task (Case, 1978, p.48n).

The M-space instrument used in the present study was an extension of the Cucui test, originally developed by De Avila (De Avila and Havassy, 1974). On each trial subjects were presented with an outline drawing of a 'Mr Kiri', on which several parts of Mr Kiri's body were coloured; subjects were allowed to view the outline for five seconds and told to remember those parts of the body which were coloured; they were then presented with a blank outline drawing of Mr Kiri and asked to point to the parts which had been coloured. Initially, each subject was presented with five different items at each of four levels, where a level was defined as the number of body parts which was coloured. Thus twenty items were presented with the level varying randomly from trial to trial.

Subjects received credit only for items which they recalled perfectly, and those who got at least four of the five level-4 items correct were given nine additional items taken from another 'Mr Kiri' M-space test developed by the Indigenous Mathematics Project (I.M.P.). These nine additional items consisted of three sets of three items at levels 5, 6, and 7.

M-space scores were determined as follows:

1. Subjects who did not get at least four of the five level-4 items correct were given scores corresponding to the highest levels for which they did get at least four of five items correct.
2. Subjects, who did get at least four of the five level-4 items correct could obtain M-space scores of 4.00, 4.33, 4.67, 5.00, 5.33, 5.67, 6.00, 6.33, 6.67, or 7.00. The integer part of the score corresponded to the highest level at which all items were correct (or, possibly, 4/5 at level-4), and the decimal part of the proportion of items at the next level which were correct.

Thus, for example, a subject who got 4/5 correct at level-4, 3/3 correct at level-5, 2/3 correct at level-6, and 2/3 correct at level 7, would have been allocated a score of 5.67. Note that the M-space test was administered to 247 of the 253 children in the larger sample.

Memory-for-Design

In this task the subject was shown fifteen line drawings one at a time for five seconds each. After each drawing was shown it was removed from vision and the subject was required to draw it as accurately as possible from memory. The drawings ranged in difficulty from a triangle to relatively complex composite designs. The test was devised by F.K. Graham and B.S. Kendall who produced a manual showing typical responses to individual drawings, and how these responses should be scored (Graham and Kendall, 1960). According to this manual each response should be given a score of 0, 1, 2, or 3, with a low score corresponding to a good response.

In the present study each response by a subject was allocated a score from 0 to 3, as recommended by Graham and Kendall, but a subject's total score over the 15 items was subtracted from 15; if this resulted in a negative number, or zero, then the subject was given an overall score of 0; if it resulted in a positive number then this was taken to be the subject's overall score for the test. Thus, for example, a subject whose

15 responses were all allocated scores of zero would have gained an overall score of 15 - 0 = 15; a subject who got 7 zeros, 4 ones, 2 twos, and 2 threes, would have gained an overall score of 1 (i.e. 15-4-4-6).

Three-Dimensional Visual Memory

In this task, which was devised by the present writers, the experimenter made several models, using thin wooden skewers and plasticene, in front of the subject, who was then told to study the completed models carefully. When the subject indicated he was acquainted with the properties of a model it was taken apart and the subject was asked to reconstruct it using the same materials. The models constructed were, in order:

(a) tetrahedron,
(b) cube,
(c) triangular prism,
(d) frustum of a tetrahedron,
(e) frustum of a square pyramid,
(f) an irregular figure, resembling a frustrum of a pentagonal pyramid, with a pentagonal base and a square top.

The interviewer made a note of any incorrect responses, but no scores were given for the task.

3.2 THE MATHEMATICS TEST

This test, which was constructed by the writers, contained twenty items, each of which required individual, verbal administration. Since written mathematics is sometimes out of touch with reality in the sense that children do not relate calculation to concrete objects (Ginsburg, 1977), whenever possible questions involved the presentation of, or thinking about, concrete objects such as stones, nuts, coins.

The first eleven items involved the application of elementary arithmetical skills. Item 13 was a Piagetian conservation of number task for which two groups of stones were presented to the subjects; item 12 consisted of the Piagetian conservation of length tasks, two sticks of equal length being used. Item 14 was the Piagetian conservation of substance task which involves pouring liquid from one container to another of different shape; item 15 was an estimation of number task, a set of

stones being used; item 16 was an estimation of substance task, using water; item 18 was an estimation of length task, using a short stick and a long stick; item 17 required subjects to choose, from a selection of five polygons (four quadrilaterals and one pentagon) one shape which was different from the others, and to explain why it was different. In item 19 subjects were shown a template on which a series of parallel line segments, of different length, was drawn; the subjects were shown Cuisenaire rods whose lengths equalled those of the parallel line segments, and asked to match the rods and lines. For item 20 the subjects were shown a 7 x 7 cardboard matrix (14 cm x 14 cm) on which thirteen squares were shaded to form a T-pattern; the subjects were then given a blank 7 x 7 matrix and twenty centicubes and asked to use the centicubes to produce the same T-pattern in the corresponding position on the blank matrix. This procedure was repeated for an F-shape, a single shaded square, and a diagonal pattern.

3.3 THE SPATIAL TASKS

'Fitting Shapes'

A children's plastic toy called 'Shapo' (Tupperware), consisting of a hollow polyhedron model with ten holes of different shapes on its surface, and ten matching shapes, was used. Each shape would fit only one hole, and it could be pushed through its corresponding hole into the interior of 'Shapo'. The ten shapes were a circle, a sector, an ellipse, a triangle, a square, a trapezium, a pentagon, a hexagon, a cross and a star. Subjects were shown 'Shapo' and the task explained; the circle was then pushed through the circular hole as an illustration of what was required. Subjects were then asked to push the other nine shapes through the corresponding holes.

The experimenter recorded each attempt and scored the task as follows: given an initial score of 18, the subject lost one mark for each incorrect matching, a maximum of two being lost for each shape.

Deregowski Models - From Line Drawings

The purpose of this task was to investigate children's understanding of diagramatic conventions; the task was devised by Deregowski (1974), and was used by Bishop (1978(b)). Subjects were shown

the five line drawings shown in Figure 1 and asked to make each of the figures out of sticks and plasticene (as used in the 3-D visual memory task). The experimenter recorded whether subjects produced two or three-dimensional models.

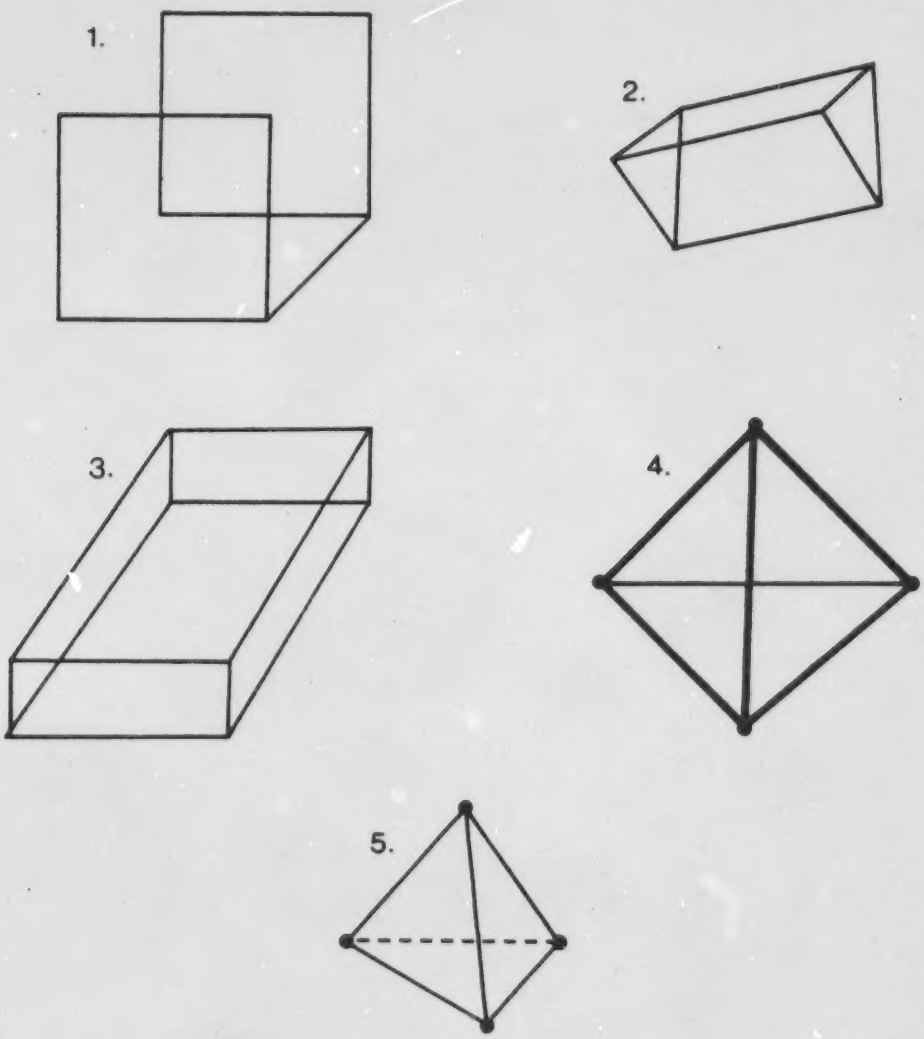


Fig.1: Five Drawing to Stick-Model Tasks (After Deregowski)

Deregowski Models - From Photographs

This task was similar to the previous Deregowski task only coloured Polaroid photographs of models (made from sticks and plasticene), instead of line drawings, were shown to the subjects. The subjects were asked to make the figures shown in the photographs. The models shown in the photographs were, in order:

(a) tetrahedron,
(b) tetrahedron (with fewer shadow cues than (a)),
(c) cube,
(d) model corresponding to the first line drawing in Figure 1,
(e) triangular prism.

For each photograph the experimenter recorded whether the subject produced a two or three-dimensional model.

Hughes' Perspective Task

An ability to co-ordinate perspectives is involved in tasks requiring recognition of how things appear from someone else's point of view. The 'three mountains task' used by Piaget and Inhelder (1967, p.210) is a well-known test of this ability. It is a relatively difficult task, however, and it was thought that another task which involved a similar ability, but was less difficult, should be included in our test battery. The Hughes' perspective task (Hughes, 1975; Hughes and Donaldson, 1979) was deemed to be appropriate for this purpose. It required a subject to decide what can be seen but not to specify exactly how it would appear. In the simplest form of the task, a model, consisting of two cardboard 'walls' intersecting to form four rooms, was made. Two small dolls were introduced and the subject was told that one of the dolls was going to hide from the other. One doll was positioned so that it could 'see' into two rooms at once; the experimenter then moved the other doll from one room to another and, for each room, asked the subject whether the 'fixed' doll could be seen by the 'moving' doll. The positions of the dolls, the number of rooms and the number of dolls were varied, but the principle of the task remained the same. The arrangements of dolls and rooms can be seen in the 'Results Sheet' (Appendix A).

Co-ordination of Perspectives Task

This task was a variation of Piaget and Innelder's 'three-mountains' task. Three wooden models, a cylinder, cone and triangular prism, formed an array in front of the subject. Around the array, at intervals of 45°, wooden markers were placed. The subject was told that photographs had been taken of

the models from each of the eight different positions marked. He was requested to look at the models from each of these positions. The experimenter and the subject sat on opposite sides of the array. Eight coloured Polaroid photographs of the models were placed in front of the subject. Four questions were asked of the type: 'Find the photograph which was taken from this position' (indicating one of the eight positions). Four questions were asked of the type: 'Where was this photograph taken from?' (indicating one of the eight photographs). For further details, see the 'Results Sheet' (Appendix A).

3.4 THE GROUP TESTS

Primary Mathematics Achievement Test

At three of the four schools (not Wonenara) a first edition of the Primary Mathematics Achievement Test (PMAT) was given to at least three classes, a grade 6 class, a grade 4 class and a grade 2 class (grade 1 class at Andra). It was on the basis of results on this test that the six children to be investigated more intensively were selected; at the three schools two boys at each of the three grade levels were selected for intensive investigation, one boy who had done very well on PMAT and another who had done relatively poorly.

The first edition of PMAT, as constructed by I.M.P., contained fifty-five questions which were set out in booklet form as a pencil-and-paper group test. For the first twenty questions the test administrators were required to read the questions to the class from a special test manual prepared by I.M.P. These first twenty questions were relatively easy and were intended to be suitable for grade 2 pupils. The remaining thirty-five questions tended to be more difficult, and were clearly intended for pupils in grades 4 to 6. These questions had to be read by the pupils themselves. Many of these latter questions involved the application of an algorithm (e.g. $15\overline{)322}$, and some required pupils to work out a method of solution (e.g. 'Hai was 11 years old on 15 January 1980. What year was Hai born?')

According to marking instructions issued by I.M.P. some questions had to be allocated more than one mark, a maximum of three marks being awarded for any one question. The maximum score which could be obtained was 70.

The present writers administered PMAT, in English, to classes at each of the three sites. (At Kero we were assisted in its administration by Mr H. Korim, Associate Director of the Mathematics Education Centre at Unitech).

On all occasions directions in the I.M.P. test manual were strictly followed. On average, it took about forty minutes to administer the test to each class; grade 2 classes took less than forty minutes because pupils in these classes were unable to do most of the questions which appeared towards the end of the test.

The Monash Assessment of Mathematical Performance

This test was administered at the same three schools as the PMAT test (not Wonenara), but it was given to grade 6 classes only at these schools.

The MAMP test was originally constructed by Clements in 1976 for use with Australian children in grades 5 to 8 (see Clements, 1980), but in the present study a Papua New Guinean version of the test was used (with, for example, dollars and cents replaced by kina and toea). Since test norms are available for Victorian children in grades 5 to 8, the use of the MAMP test in the present study permitted comparison of performances of grade 6 pupils in three Papua New Guinean Community Schools with those of children in grades 5 to 8 in Victoria.

The MAMP test contains thirty-six items, twenty of which are numeration items, eight mathematical space items, and eight mathematical logic and language items. It has been used in large research projects involving children aged between 9 and 14 years, and the difficulty of the test is such that fifth-grade children in Victoria have averaged 23 questions correct out of 36.

The Mathematical Language Test

This test was developed by Associate Professor P.L. Jones during the time we were at Andra. The test, which was given to grade 6 pupils at Andra (and was not administered in the three other Community Schools involved in the study), contained seventeen questions. The purpose of the test was to determine whether children understood various ways important mathematical words (such as 'more', 'less') are used in English. Thus, for example, the first six questions on the test were:

1. Which is more, 10 or 13?
2. Which number is 1 more than 5?
3. John has 5 fish and Bill has 7 fish. Who has more fish?
4. Patrick has 2 more fish than Christopher. If Patrick has 8 fish, how many fish does Christopher have?
5. The number 8 is 2 more than what number?
6. What is 3 more than 6?

A similar set of questions tested understanding of 'less'. Two questions required understanding of 'longer' and 'shorter', and there were three 'language-of-time' questions (e.g. 'It is now 5 o'clock. What time was it 3 hours ago?')

The test was given to grade 6 pupils at Andra as a pencil-and-paper test. Questions were not read to pupils. A copy of the Mathematical Language Test is included as Appendix B.

3.5 THE INTERVIEW

Each subject in the primary sample was individually interviewed. In each interview an attempt was made to elicit details of the subject's daily life, his attitudes to school, to mathematics, and to school mathematics in particular. Also, information was requested on the subject's attitude to examinations, his ambitions, and the extent to which home life was supportive of school life. Other matters which arose naturally during the course of an interview were also pursued.

In most cases the interviews were conducted in English but, whenever necessary, tok pisin or tok ples was used. A copy of the interview schedule is included as Appendix C.

4. RESULTS

This section will be divided into five subsections concerning memory tasks, the mathematics test, spatial tasks, the group tests, and the interview, respectively. In each subsection an introduction will be given, followed by a tabular summary of results and some brief comments. No attempt will be made to synthesize the implications of results in one subsection with those of another, this being left for Section 5. Note that in all tables where summaries of grade 2 results are given, it has been assumed, for the purposes of analysis, that first-grade pupils at Andra can be regarded as second-grade pupils.

4.1 MEMORY TASKS - RESULTS

3 x 4 Matrix and Memory Space Tasks

It will be recalled that an expanded sample containing 253 children took visual memory tasks 3, 7, 8, which required them to attempt to replace twelve familiar objects, numerals, and nonsense symbols, respectively, on a 3 x 4 matrix. Also, 247 of the same 253 children took the M-space test.

Table 1 shows means and standard deviations of various groups on these tasks. The three groups, N(CS), N(IPS), Exp, to which reference is made in Table 1, are defined as follows:

GROUP N(CS): National children attending Andra, Kabagap and Kero Community Schools.

GROUP N(IPS): National children attending the Lae International Primary School.

GROUP Exp : Expatriate children attending the Lae International Primary School.

Details concerning the six Wonenara (Eastern Highlands) subjects are also given.

TABLE 1

Visual Memory and Memory Space of Children Attending PNG Community Schools and Lae International Primary School

Grade	Group	No. of Pupils	Vis.Mem. (Objects) $\bar{X}$	Vis.Mem. (Objects) SD	Vis.Mem (Numerals) $\bar{X}$	Vis.Mem (Numerals) SD	Vis.Mem. (Symbols) $\bar{X}$	Vis.Mem. (Symbols) SD	M-Space $\bar{X}$	M-Space SD
2	N(CS)	45	7.6	3.4	5.8	3.6	6.8	3.9	2.7	1.0
	N(IPS)	7	9.3	2.6	6.6	3.2	6.6	2.8	3.6	1.2
	Exp	42	10.1	2.1	6.6	2.8	7.0	2.4	2.9	0.9
4	N(CS)	33	10.2	2.6	7.2	3.3	8.5	3.3	3.1	1.1
	N(IPS)	5	11.4	1.4	7.8	3.2	7.6	3.5	3.2	1.2
	Exp	48	11.1	1.8	7.0	3.0	9.8	2.2	3.7	1.2
6	N(CS)	36	10.2	2.4	7.4	3.3	8.9	2.8	3.6	0.9
	N(IPS)	5	11.0	1.4	8.2	2.4	9.2	2.6	3.8	1.1
	Exp	26	11.8	1.0	7.6	2.8	9.3	2.7	4.5	1.3
EASTERN HIGHLANDS		6	10.3	2.3	8.2	3.8	7.3	3.7	NOT AVAILABLE	

From Table 1 the following four observations can be made:

(a) While means of the three groups were not usually very different from each other, for the same task at the same grade level, there was a slight tendency for children attending the International Primary School to have done better than children attending Community Schools.

(b) Grade 6 children in the sample tended to outperform other children in the sample. Grade 4 children tended to outperform grade 2 children.

(c) For the three visual memory tasks involving the 3 x 4 matrix, subjects tended to do best on the task involving replacement of familiar objects, next best on the task involving nonsense symbols, and worst on the task involving numerals.

(d) On the M-space test differences between the groups favoured National children attending the International Primary School at the grade 2 level, but Expatriate children at grades 4 and 6.

The interview sample was given a much more extensive set of memory tasks. On the 3 x 4 matrix task requiring replacement of twelve unfamiliar objects, performances were at about the same level as those for the 3 x 4 task with familiar objects. Details of results will not be given here, although it should be noted that the first two of the above four observations for the larger sample were true in this case, also. Details of the results on the 2 x 3 matrix tasks will not be given, either, for most children gained perfect scores on these tasks.

Sequential and Simultaneous Linear Digit Span Tasks

Table 2 shows means of groups N(CS), N(IPS), Exp (as defined for Table 1, except interview sample subjects only are considered) on linear strings of digits presented (a) visually and simultaneously, (b) visually and sequentially, (c) orally and sequentially, and (d) orally and sequentially but digits have to be repeated backwards. Details of the six Wonenara (Eastern Highlands) subjects are also given.

TABLE 2

Visual Simultaneous, Visual Sequential,
Auditory Digit Spans (Forwards and Backwards)
of Community School and International Primary School Children.

Grade	Group	No. of Pupils	Vis.Sim. $\bar{X}$	Vis.Seq $\bar{X}$	Auditory Forwards $\bar{X}$	Auditory Backwards $\bar{X}$
2	N(CS)	6	4.2	3.7	4.5	3.3
	N(IPS)	3	5.0	3.7	4.3	2.7
	Exp	4	5.5	4.8	5.0	2.8
4	N(CS)	6	5.2	4.5	5.0	4.0
	N(IPS)	3	6.3	5.0	6.0	3.5
	Exp	3	5.7	4.7	5.3	4.0
6	N(CS)	6	6.7	5.5	5.8	4.0
	N(IPS) (gr.5)	2	6.5	5.5	6.0	4.0
	Exp	5	6.8	4.8	6.2	4.2
EASTERN HIGHLANDS		6	6.0	4.3	3.8	3.0

While it should be emphasized that the sizes of the samples from which data for Table 2 were obtained were much smaller than those for Table 1, several observations similar to those made for Table 1 can be made:

(a) While the means of the three groups were usually not very different from each other, there was a slight tendency for children attending the International Primary School to have done better than children attending the Community Schools. (Such differences would not be statistically significant, however.)

(b) Grade 6 children in the sample tended to outperform other children in the sample. Grade 4 children tended to outperform grade 2 children.

(c) When performances on the two visual memory tasks (simultaneous and sequential) and the (forwards) auditory memory task are compared, there is a tendency for subjects to have done best on the simultaneous visual memory task, next best on the auditory task, and worst on the sequential visual memory task. This is the same order of difficulty as that obtained by Torgeson et al. (1978, p.453).

(d) The unschooled, or relatively unschooled, children in the Wonenara (Eastern Highlands) group performed poorly on the auditory tasks. While there may be a chance variation resulting from the small sample size, it is interesting that the Wonenara sample performed at about the same level as grade 4 children in the sample on the visual memory tasks summarized in Tables 1 and 2.

Memory-for-Design

The results on the Graham and Kendall Memory-for-Design test are given in Table 3. The groups N(CS), N(IPS) and Exp are as defined above.

TABLE 3

Memory-for-Design Results

Group	Grade 2 $\bar{X}$	Grade 4 $\bar{X}$	Grade 6 $\bar{X}$
N(CS)	9.0	9.8	11.8
N(IPS)	5.3	6.3	10.0
Exp	7.0	12.0	12.0

The following observations can be made about Table 3:

(a) All groups showed an improvement in performance from grade 2 to grade 6.

(b) The National children attending the Community Schools tended to do better than National children attending the International Primary School.

Three-Dimensional Visual Memory

Thirty-eight subjects in the smaller sample did the 3-D Visual Memory task (the Wonenara group did not). Table 4 gives the proportion of correct responses for each of the six models to be constructed; two groups are compared: eighteen National children attending Andra, Kabagap and Kero Community Schools, and twenty pupils, National and Expatriate, attending Lae International Primary School. The models were numbered as follows:

1. Tetrahedron
2. Cube
3. Triangular prism
4. Frustum of tetrahedron
5. Frustum of square pyramid
6. Irregular figure, resembling a frustum of pyramid with pentagonal base and square top.

TABLE 4

Three-Dimensional Visual Memory Results

	Proportion of Correct Responses on Model ...					
Group	1	2	3	4	5	6
Comm. Schl pupils	.70	.90	.90	.85	.90	.40
Inter.Primary Schl pupils	.85	1.00	.90	.85	.85	.35

From Table 4 it can be seen that there is very little difference between the performances of the two groups. The only model which presented some difficulty for both groups was model 6. These results are of some interest given that the majority of the Community School pupils had had little or no experience in model making, whereas a majority of the International Primary School pupils had had such experience.

4.2 MATHEMATICS TEST - RESULTS

The only subject in the interview sample who was unable to count twenty-five stones was an Expatriate grade 2 pupil at the International Primary School. The three unschooled children in the Eastern Highlands had no difficulty in counting to 25 in English, despite the fact that they knew very little English. When asked how they had learned to count in English they said that boys from their village who had been to school had taught them.

Only three pupils responded incorrectly to the question: 'There are three men on my right (hand) and five men on my left (hand). How many men altogether?' One of the subjects who gave an incorrect answer was a grade 1 pupil at Andra, another was in Grade 4 at Kabagap, and the other was a grade 6 Expatriate boy at the International Primary School. All six Eastern Highlands subjects obtained the correct answer. On another addition problem, 'I have fifty toea in one hand and twenty toea in the other hand. How many toea do I have altogether?', nine incorrect responses were given, six from Community School subjects and three from International Primary School subjects. One of the six Eastern Highlands subjects gave an incorrect answer.

For subtraction, twelve incorrect responses were given to the question, 'I have seventy toea. I give forty toea to him. How many toea do I have now?' Of the twelve incorrect responses, seven came from subjects at Community Schools and five from subjects at the International Primary School. All six Eastern Highlanders obtained the correct answer. Seven incorrect responses were given to the question, 'I go to the trade store with one kina. I buy a big tin fish for sixty toea. How many toea do I have left?'; four of the incorrect responses came from Expatriate children in grades 2, 4, and 6 at the International Primary School.

Two questions concerned multiplication and division. Eleven National children (of whom two were at the International Primary School), but only two Expatriate children, responded incorrectly to the question, 'There are four

men, and each has three pigs. How many pigs are there altogether?' For the division question, twelve betel nuts were placed in front of three plates (identical in appearance) and subjects were asked how many betel nuts each plate would get if each plate got the same number. Seven National children (of whom three were at the International Primary School) gave incorrect responses, but all Expatriate children in the interview sample were correct.

There were four questions on fractions, and these proved to be more difficult than those involving operations on natural numbers. For the first two fraction questions subjects were shown six stones and asked to pick up (a) one-half, (b) one-third of them; for the other two questions subjects were handed a knife and a piece of sugar-cane and asked to indicate where they would cut the sugar-cane so that it would be divided into (a) two, (b) three equal pieces. Altogether fifty-four errors were made by the interview sample on these four questions, and of these forty-seven were made by National children. Most of the errors occurred on the 'one-third' questions.

Conservation Tasks

The proportions of children conserving number, length, and substance, in groups N(CS), N(IPS), Exp (defined earlier), are shown in Table 5. Proportions for the Eastern Highlands sample are also shown.

TABLE 5

Conservation of Number, Length, and Substance
by Community School and International Primary School Children

Grade	Group	No. of Pupils	Proportion who conserved ... Number	Length	Substance
2	N(CS)	6	1.00	0.50	0.33
	N(IPS)	3	0.67	0.33	0.33
	Exp	4	1.00	0.50	1.00
4	N(CS)	6	1.00	0.67	0.67
	N(IPS)	3	1.00	0.33	1.00
	Exp	3	1.00	0.67	1.00
6	N(CS)	6	1.00	0.67	0.83
(5)	N(IPS) (gr.5)	2	1.00	1.00	1.00
	Exp	5	0.80	0.80	0.80
Eastern Highlands		6	1.00	0.83	0.50

From Table 5 the following observations can be made:

(a) Only two subjects did not conserve number. The two exceptions both attended the International Primary School. One was a National pupil in grade 2 and the other an Expatriate pupil in grade 6.

(b) With the exception of the grade 5 International Primary School National pupils, all groups had members who did not conserve length.

(c) Of the twelve Expatriate subjects, only one, who was in grade 6, did not conserve substance. Of the eighteen Community School children (not including the Wonenara group) seven did not conserve substance.

(d) Although all six Wonenara subjects, whose average age was about fourteen years, conserved number, one did not conserve length and three did not conserve substance.

Estimation Tasks

The proportions of children who gave reasonable responses (within one unit of measure) on estimation tasks involving number, length and substance, in groups N(CS), N(IPS), and Exp (defined earlier), are shown in Table 6. Proportions for the Eastern Highlands sample are also shown.

Most groups performed better on the estimation of length task than on the other estimation tasks. The estimation of length task required subjects to judge how many small sticks of a fixed length would be needed to make up a larger stick. While such a task might be expected to be of some use in village life (e.g. in constructing traditional huts), it is likely that the other estimation tasks were 'foreign'. In particular, the estimation of substance task, which required subjects to judge the number of small containers which would need to have been filled in order to fill a large container, would not be regarded as relevant by most villagers.

TABLE 6

Proportions of Children Who Gave Reasonable Responses on Estimation Tasks

Grade	Group	No. of Pupils	Proportion which correctly estimated ... Number	Length	Substance
2	N(CS)	6	0.00	0.67	0.55
	N(IPS)	3	0.67	1.00	0.33
	Exp	4	0.25	1.00	0.25
4	N(CS)	6	0.67	0.67	0.17
	N(IPS)	3	0.67	1.00	0.33
	Exp	3	0.67	1.00	0.67
6 (5)	N(CS)	6	0.67	0.83	0.67
	N(IPS) gr(5)	2	1.00	0.50	1.00
	Exp	5	0.80	0.80	0.60
Eastern Highlands		6	1.00	0.83	0.33

Shape Discrimination

Item 17 of the Mathematics Test required subjects to look at five shapes, four of which were quadrilaterals and the other a pentagon, and to say which one was different, and why. Only two subjects did not select the pentagon as the odd shape out. When asked to explain their selections, subjects usually gave one of two explanations. Some referred to shape (for example, 'it's a nouse'); others referred to the number of sides. Of the forty-two subjects who gave the pentagon as their answer, thirty-three referred to the shape and nine referred to the number of sides. Interestingly, 27 percent of the Community School subjects and 46 percent of the International Primary School subjects referred to the number of sides. The majority of subjects, however, were tied to the perceptual aspects of the figures rather than to the more abstract 'number of sides'.

4.3 THE SPATIAL TASKS - RESULTS

'Fitting Shapes'

The results of the shape discrimination task, using the Tupperware 'Shapo' toy, are given in Table 7. (The groups N(CS), N(IPS) and Exp are as previously defined, and the maximum possible score for an individual was 18.)

TABLE 7

'Fitting Shapes' Results (Interview Sample Only)

Group	Grade 2 $\bar{X}$	Grade 4 $\bar{X}$	Grade 6 $\bar{X}$
N(CS)	11.7	10.8	16.1
N(IPS)	15.3	16.3	17.0 (gr.5)
Exp	16.3	17.0	17.4

The following comments are made with respect to Table 7.

(a) At grade 2 and grade 4 levels the performances of the Community School children were much lower than those of International Primary School children. By grade 6, however, the differences had narrowed considerably.

(b) Many subjects confused different shapes which had perceptual similarities (e.g., sector and triangle, pentagon and hexagon). Subjects tended to pay more attention to shape than to the number of sides.

Deregowski Models: From Line Drawings and Photographs

The children responded to the tasks of making the objects shown in the line drawings and photographs by producing either two-dimensional or three-dimensional models. The proportions of models which were three-dimensional, for the groups N(CS), N(IPS) and Exp, are shown in Table 8.

TABLE 8

Proportions of 3-D Responses on 'Deregowski' Tasks (Interview Sample Only)

Task	Group	Proportion of 3-D Responses in ... Grade 2 $\bar{X}$	Grade 4 $\bar{X}$	Grade 6 $\bar{X}$
Line drawings	N(CS)	0.10	0.13	0.43
	N(IPS)	0.60	0.60	0.90(gr.5)
	Exp	0.55	0.80	0.68
Photographs	N(CS)	0.43	0.40	0.60
	N(IPS)	0.80	0.80	1.00(gr.5)
	Exp	0.70	0.80	1.00

The following observations can be made about the results in Table 8:

(a) Most of the Community School subjects, in all three grades, produced two-dimensional responses, whereas a majority of International Primary School subjects, both National and Expatriate, in all three grades, produced three-dimensional responses.

(b) Although Community School subjects were more likely to give three-dimensional responses to photographic stimuli than to line drawings, the proportions of three-dimensional responses on the photographs task was still below corresponding proportions for International Primary School subjects at the same grade levels.

(c) For all groups, grade 6 children produced higher proportions of three-dimensional responses than grade 2 children. The International Primary School subjects in grades 5 and 6 gave three-dimensional responses on the photographs task, whereas only 60% of the Community School subjects did this.

The Hughes Task and the Co-ordination of Perspectives Task

Of these two tasks, the Hughes 'hiding' task is the easier and is well suited to young children. It attempts to determine whether subjects are spatially egocentric without complicating the issue by requiring them to decide precisely how something appears when seen from a different viewpoint. It is the coordination of perspectives task which is concerned with that latter aspect.

All of the forty-four subjects in the 'interview' sample, both in the Community Schools and the International Primary School, were successful at the Hughes task, indicating that, at least within the limits of the task, they are not spatially egocentric.

The results of the co-ordination of perspectives task, however, present a different picture. The subjects who did this task were the eighteen children in the 'interview' sample from Andra, Kabagap and Kero Community Schools (the Wonenara group was not given this task) and the twenty children in the 'interview' sample from the International Primary School. In addition, an additional sample was used, comprising thirteen boys and fifteen girls in grade 6 at Andra Community School. The results for the 'interview' sample and the additional sample will be presented separately.

In Table 9, the results of the 'interview' sample are given. In this task, questions relating to eight photographs taken around an array of models were asked; the summary results in Table 9 show average scores out of a possible eight for each of the previously defined groups, N(CS), N(IPS), Exp, at three grade levels.

TABLE 9

Mean scores (Max. Possible Score of 8) on the Co-ordination of Perspectives Task ('Interview' Sample Only)

Group	Grade 2 $\bar{X}$	Grade 4 $\bar{X}$	Grade 6 $\bar{X}$
N(CS)	2.3	1.7	3.3
N(IPS)	2.0	5.0	4.7(gr.5)
Exp	3.0	7.3	5.7

The following observations may be made from Table 9.

(a) Grade 2 pupils in each group experienced difficulty with the task.

(b) International Primary School children in grades 4, 5 and 6 did better on the task than Community School children, who found the task difficult.

In Table 10 results of boys and girls in the additional sample at Andra Community School are summarized.

TABLE 10

Mean scores of Grade 6 Pupils at Andra C.S.
on the Co-ordination of Perspectives Task

Group	No. of pupils	Mean Score/8	Standard Deviation
Boys	13	4.4	1.2
Girls	15	1.7	1.6

The differences between the means shown in Table 10 are statistically significant at the 0.01 level of confidence (2-tailed t-test). However, the boys also did much better than the girls on the Primary Mathematics Achievement Test (PMAT), so it would appear to be the case that the grade 6 Andra boys were intellectually superior to the grade 6 Andra girls.

4.4 THE GROUP TESTS

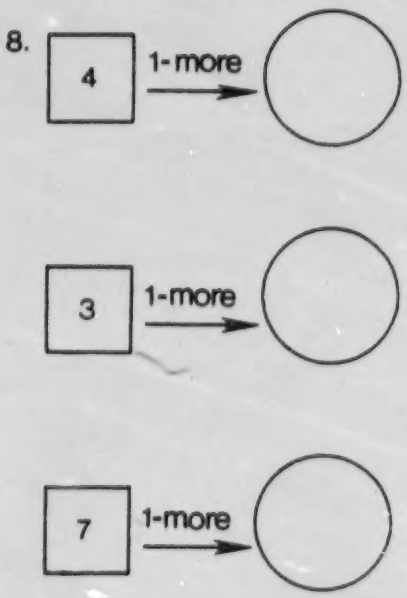
In this section, results of the three group tests will be presented. The tests were administered to a variety of samples, so careful attention should be given to the description of the sample whose results are being summarized at any given time.

The Primary Mathematics Achievement Test (PMAT)

Although PMAT was administered in a number of Community Schools as part of the I.M.P. research programme, here we will present the results of one school, Kero, where the authors carried out the testing for the I.M.P. The results presented below give the percentage of correct responses of Kero pupils in grades 2, 4 and 6 to selected questions on PMAT. The sample consisted of sixty-nine grade 2 pupils, thirty-three grade 4 pupils, and thirty-three grade 6 pupils.

Question 8 (PMAT)

[Instructions: Look at the numbers in the boxes. Think of a number 1-more than the number in the box. Write the number in the circle.]

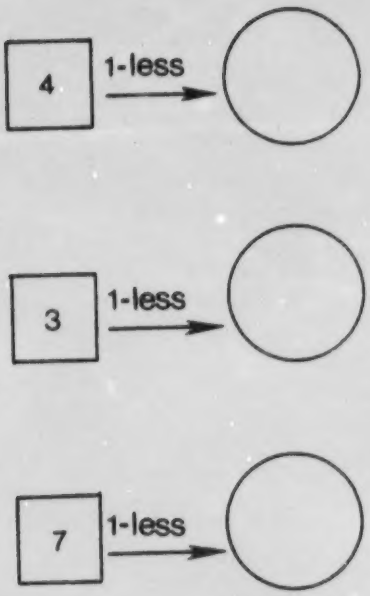


	% correct, Kero C.S.		
Question	gr.2	gr.4	gr.6
8(a)	48	88	88
8(b)	43	88	85
8(c)	45	88	88

Note that the instructions were read to the pupils. Results indicate that slightly more than 50% of the grade 2 pupils, and about 12% of the grades 4 and 6 pupils, did not understand the expression '1-more' in the sense in which it was used in this question.

Question 9 (PMAT)

[Instructions: Look at the numbers in the boxes. Think of a number 1-less than the number in the box. Write the number in the circle.]



	% correct, Kero C.S.		
Question	gr.2	gr.4	gr.6
9(a)	14	88	91
9(b)	16	82	85
9(c)	13	82	85

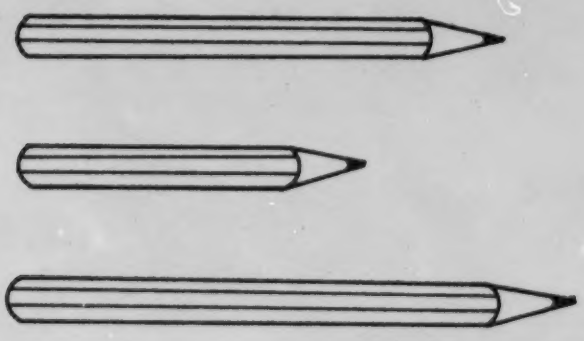
For grades 4 and 6, the pattern of results here is similar to that for Question 8. For the grade 2 pupils, however, only about 15% understood the use of the expression '1-less' used in the given sense.

Results on three other PMAT questions are now presented.

Question 11 (PMAT)

[Instructions: Look at the 3 pencils. Put the number 1 on the shortest.
Put the number 2 on the next longest pencil.
Put the number 3 on the longest pencil.]

11.

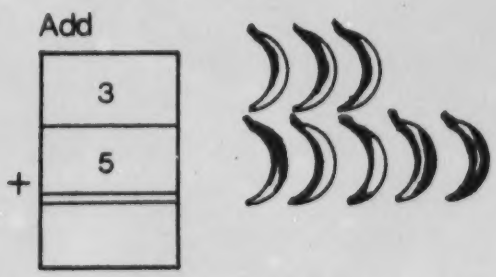


% correct, Kero C.S.		
gr.2	gr.4	gr.6
43	76	100

Question 15 (PMAT)

[Instructions: Add the bananas.]

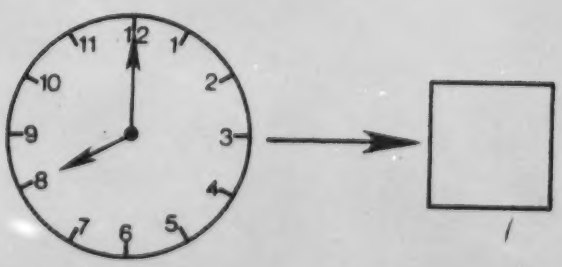
15.



% correct, Kero C.S.		
gr.2	gr.4	gr.6
83	97	97

Question 19 (PMAT)

[Instructions: Look at the clock. What time does it show?]



% correct, Kero C.S.		
gr.2	gr.4	gr.6
43	88	88

The above three questions, which involved reasonably direct applications of skills taught in the classroom, did not present most Kero children in grades 4 and 6 with many difficulties. However, there was a sharp drop in performance on word problems which required the formulation of appropriate problem solving strategies. For example, only one of the 135 children tested obtained the correct answer to the question 'Hai was 11 years old on 15 January 1980. What year was Hai born?'

The Monash Assessment of Mathematical Performance (MAMP)

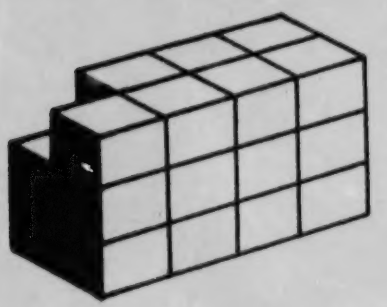
The results of MAMP will be presented in four sections which will deal with performance on selected questions relating to:

1. Spatial skills and knowledge of diagrammatic conventions;
2. Understanding mathematical language and logic;
3. Calculations and 'survival' problems;
4. Time.

For each question, the performances of three groups, Vic, IPS, and CS will be given. 'Vic' represents a very large sample of sixth-grade pupils drawn from 105 Victorian primary schools. 'IPS' represents all sixth-grade pupils attending the Lae International Primary School in 1980. 'CS' represents all sixth-grade pupils attending Andra, Kabagap and Kero Community Schools in 1980. In each case, percentages of correct responses are given.

Section 1. Spatial Skills and Knowledge of Diagrammatic Conventions

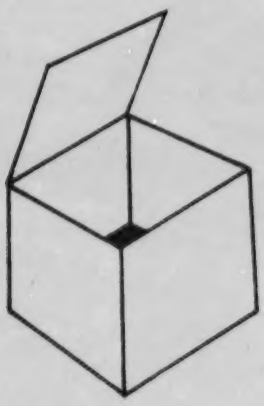
Question 9 (MAMP)



How many blocks are there in this stack?

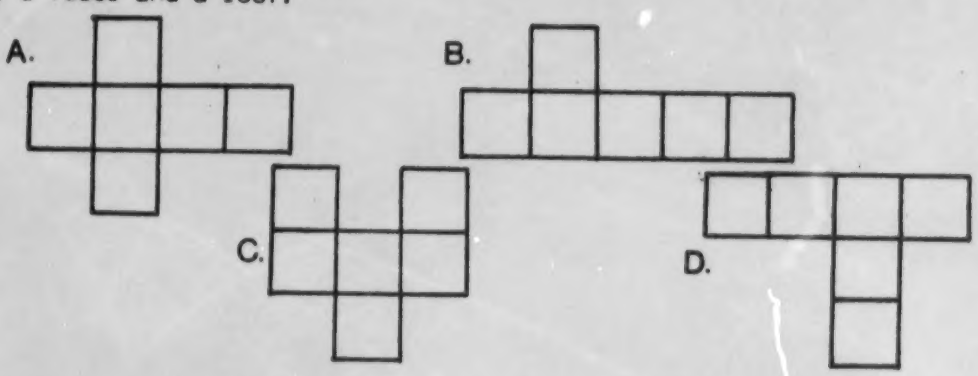
% correct		
Vic	IPS	CS
68	62	18

Question 16 (MAMP)



% correct		
Vic	IPS	CS
78	92	19

Which of these patterns below could be folded to make a box which has four walls, a floor and a roof?



It is interesting to observe, in passing, that the results on these two questions would appear to be consistent with those for the Deregowski task (line diagrams), which indicated that many Community School children do not understand the conventions by which three-dimensional objects are represented diagrammatically.

Section 2. Understanding Mathematical Language and Logic

Question 8 (MAMP)

Altogether there are 10 children in a room and there are 4 more girls than boys. How many boys are there in the room?

% correct		
Vic	IPS	CS
37	57	7

Question 20 (MAMP)

What is eighteen more than eighty-seven?

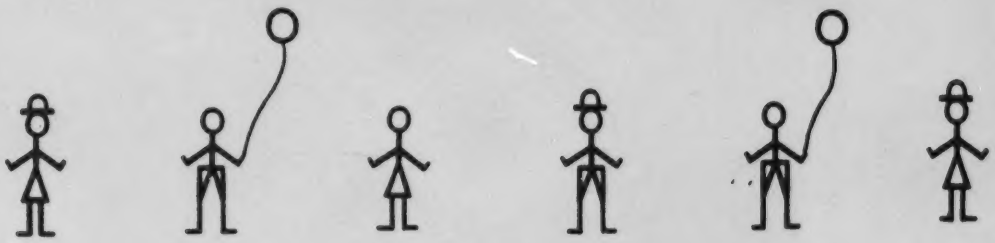
% correct		
Vic	IPS	CS
70	84	19

Question 22 (MAMP)

The number 101 is two less than which number?

% correct		
Vic	IPS	CS
64	81	7

These diagrams are for questions 4 and 5.



Anne Brian Cathy David Peter Emma

Question 4 (MAMP)

Name each child who is a girl AND is wearing a hat.

% correct		
Vic	IPS	CS
88	92	62

Question 5 (MAMP)

Name each child who is a girl OR is holding a balloon.

% correct		
Vic	IPS	CS
50	76	3

Question 7 (MAMP)

Jack, John and Jenny all have birthdays on the 1st of January, but Jack is 1 year older than John, and John is 3 years younger than Jenny. If Jenny is 10 years old, how old is Jack?

% correct		
Vic	IPS	CS
65	76	5

The results given for the six questions above indicate that questions requiring comprehension of important aspects of mathematical language, including quantifiers, polarized comparatives, logical connectives, and implications, present much more difficulty to Community School children than to children of the same age for whom English is the first language. Evidence showing that the main source of the Community School children's difficulty with Questions 8, 20, and 22 (above), for example, was faulty comprehension rather than faulty computation will be given shortly (see The Mathematical Language Test). With respect to Questions 4 and 5, above, it is interesting to observe that the current Mathematics for Community Schools syllabus stresses the need for children, from the early grades, to be able to use the conjunction 'and' and the disjunction 'or'. Clearly, a significant proportion of Community School children in grade 6 do not have a thorough understanding of these terms.

Section 3. Calculations and 'Survival' Problems

Question 21 (MAMP)

What number does 376 + 23 + 9 equal?

	% correct		
	Vic	IPS	CS
Q.21	76	84	55

Question 23 (MAMP)

$$\begin{array}{r} 940 \\ -586 \\ \hline \end{array}$$

Q.23	74	86	56

Question 24 (MAMP)

		% correct		
		Vic	IPS	CS
37 x 4 =	Q.24	86	86	53

Question 26 (MAMP)

What is the missing number?

60, ___, 48, 42, 36.

Q.26	80	78	28

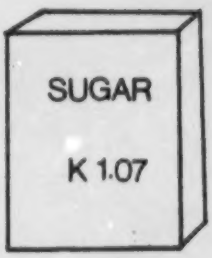
Question 36 (MAMP)

If 5 pens cost K6, how much should 3 of the same pens cost?

Q.36	32	30	1

Question 34 (MAMP)

Jim buys the box of sugar. He pays the shopkeeper K2.00. How much change should he get?



% correct		
Vic	IPS	CS
88	89	25

Community School children tended to cope better with questions of the straightforward computational variety, such as Questions 21, 23, and 24, than with other types of questions on the MAMP test. Relative performance dropped sharply if a question required even a simple problem solving strategy to be formulated. (See, for example, Questions 26, 36, and 34.)

Question 30 (MAMP)

If the time is 8 o'clock in the morning what was the time 10 hours ago? (Make sure you include a.m. or p.m. as part of your answer.)

% correct		
Vic	IPS	CS
59	57	7

Question 27 (MAMP)

What is the time shown on the clock?

% correct		
Vic	IPS	CS
93	97	27

Question 28 (MAMP)

On the clockface on the answer sheet draw where the hands will be 40 minutes after the time shown on the clock in Question 27.

% correct		
Vic	IPS	CS
62	49	1

Results for Question 27 indicate that only slightly over a quarter of the sixth-grade Community School children could read the time shown on the clock. This result should be contrasted with the much better performance of Community School children on Question 19 on PMAT (see earlier).

It would appear that simple problem solving exercises involving the addition or subtraction of time were beyond most of the Community School children.

The Mathematical Language Test

The results of a pilot study, by Jones, using his Mathematical Language Test with sixth-grade children at Andra, were of sufficient interest to justify administering the test to a larger group of children. Subjects from Community and International Primary Schools in Lae were given the Test in July and August 1980, and data thereby obtained will be summarized here. For further details of Jones' study into difficulties experienced by Community School children with certain aspects of mathematical language, see Jones (1981b).

Table 12 shows mean scores (maximum possible score of 17) on the Mathematical Language Test of pupils in grades 2, 4 and 6 at Community Schools and two International Primary Schools in Lae. (Note that Community School children in grade 2 were not tested.)

TABLE 12

Performances of Pupils Attending Community Schools and Two International Primary Schools on the Mathematical Language Test (see Jones, 1981)

Group	Grade 2		Grade 4		Grade 6	
	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$
Community Schools	-	-	96	6.2	58	9.2
Inter.Primary Schools	72	9.5	74	13.8	79	15.3

From Table 12 it would appear that grade 6 children in Community Schools typically had about the same level of comprehension of mathematical language as grade 2 children in the International Primary Schools. Interestingly, additional data obtained by Jones (1981b) gives the mean of National students in grade 9 at Provincial High Schools as 14.0 (N=76) which is about the same as the mean for grade 4 International Primary School children (see Table 12).

Jones also considered the question of whether National children attending International Primary Schools performed differently on the Mathematical Language Test for (a) Expatriate children attending International Primary Schools, and (b) National children attending Community Schools. Table 13 shows mean scores for National and Expatriate children, attending Lae International Primary School, in grades 2, 4, and 6.

TABLE 13

Performances of Expatriate and National Children, Attending the Lae International Primary School, on the Mathematical Language Test (see Jones, 1981)

Group	Grade 2		Grade 4		Grade 6	
	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$
Expatriate	42	9.8	48	14.1	26	15.8
National	7	6.1	5	10.0	5	12.4

By comparing Tables 12 and 13 it can be seen that the mean of National children in grade 2 at the International Primary School is approximately equal to that of grade 4 children in Community Schools in Lae, and that the mean of National children in grade 4 at the International School is slightly greater than that for the grade 6 Community School children. In general, means of groups of National children are less than those of groups of Expatriate children at the same grade levels.

The summaries of group data, presented in Tables 12 and 13, mask the seriousness of the problems many National children are experiencing when attempting to comprehend mathematical language. In order to draw attention to these difficulties the following analysis of performances by National children in grades 4 and 6 at one Community School in Lae is presented; the performances are fairly typical of National children in grades 4 and 6 throughout Papua New Guinea. In each case percentages of correct responses on particular questions from the Mathematical Language Test are given.

TABLE 14

Performances of Pupils in Grades 4 and 6 at a Community School in Lae on Five Questions from the Mathematical Language Test

Question	Percentage Correct in ... Grade 4 (N = 33)	Grade 6 (N = 58)
What is 3 more than 6?	36	50
Which number is 2 less than 5?	58	66
The number 8 is 2 more than what number?	15	29
The number 6 is 2 less than what number?	0	16
My pencil is 8 cm long. John's pencil is 2 cm shorter than mine. How long is John's pencil?	0	22

Error analysis by Jones (1981b) reveals, clearly, that the National children had considerable difficulty with expressions like 'more than' and 'less than'. For example, many children responded to the question 'What is 3 more than 6?' by writing 'No'; usually these children had erroneously interpreted the question as meaning 'Is 3 more than 6?'. Other children responded to the question 'What is 3 more than 6?' by writing '6'; usually these children had interpreted the question as meaning 'Which is more, 3 or 6?'

The comprehension of word problems requiring addition or subtraction of time was also a source of unexpected difficulty for National children. Table 5 shows the performances of the same pupils in grades 4 and 6 who provided the data for Table 14, on three word problems concerned with 'time'. Error analysis by Jones revealed that many pupils simply did not grasp the meaning of expressions like 'What time will it be in 2 hour's time?'; 'What time was it 2 hours ago?'; and 'For how many hours is it open?'

TABLE 15

Performances of Pupils in Grades 4 and 6 at a Community School in Lae on Three 'Time' Questions from the Mathematical Language Test

Question	Percentage Correct in ... Grade 4 (N = 33)	Grade 6 (N = 58)
It is now 2.00 o'clock. What time will it be in 2 hours' time?	18	53
It is now 5 o'clock. What time was it 3 hours ago?	6	45
A trade store is open from 1.00 p.m. to 4.00 p.m. For how many hours is it open?	6	17

It can be seen, from the questions given in Tables 14 and 15, that calculations required by items on the Mathematical Language Test were extremely simple. Thus, it is reasonable to assume that poor performances on the Test were mainly the result of faulty reading, comprehension, or transformation (using the terminology introduced by Newman - see Clements, 1980).

4.5 THE INTERVIEW

There was marked difference between the Community School pupils' and the International Primary School pupils' responses to a question regarding the amount of homework done. All Community School children reported doing little schoolwork outside hours. Most of the pupils did not have adequate facilities at home for doing homework, many had a long walk home from school and some helped their parents when they reached home. All International Primary School pupils interviewed reported doing homework and additional reading each weeknight and on the weekend, the amount varying with the pupil's grade level. Thus, over six years of primary schooling, an International Primary School pupil might do in excess of 1000 hours more schoolwork than his counterpart in the Community School.

The interviews also revealed that Community School children, in comparison with children attending the International Primary School, had had relatively few opportunities to develop skills involved in understanding depth perception in drawing and photographs; also, conventions associated with the representation of three-dimensional objects as drawings on a two-dimensional page were rarely known. None of the four Community Schools visited had electricity, and, consequently, few of the pupils had ever seen slides, movies or videotapes. Most pupils had not seen many photographs, and some pupils had had few opportunities to draw pictures. None of the Community School children interviewed had more than two or three books at home. By contrast, the International Primary School provided a spatially rich environment for its pupils. There was a special Art room in the school where children regularly received instruction on drawing pictures and making models; in addition, the school program provided many opportunities for viewing movies and videotapes. Needless to say, there were many drawings, photographs, and books in the pupils' homes, and most of the children watched movies at home or in the local cinema. Undoubtedly, these experiences helped the International Primary School children to develop spatial skills associated with mathematics learning (Lean and Clements, 1980).

There were interesting contrasts between the language experiences of different groups of children. Each of the Community School children who was interviewed spoke, and heard, English in the classroom only. In the playground, and at home, tok pisin or tok ples was invariably spoken. And while some of the National children attending the International Primary School reported speaking tok pisin at home, all of them said that they mostly

spoke English in the playground. It is little wonder, then, that National children attending the International Primary School performed much better than Community School children on the Mathematical Language Test.

In response to the question 'What do you learn in mathematics?' both Community School and International Primary School children tended to confine their answers to expressions which implied that mathematics consisted of nothing more than computations. 'Sums', 'plus', 'take-aways', and 'times' were typical answers. Rarely did a pupil give an answer which suggested that mathematics was something more than computation, although occasionally there was a reference to 'blocks'. (Attribute blocks and Dienes' multibase arithmetic blocks are sometimes used in Community Schools and the International Primary School.) A few pupils reported that mathematics was their favourite subject, but it was more common for more neutral, or negative attitudes towards mathematics to be expressed. Rarely did a pupil explain why mathematics might be important in everyday life, although some pupils mentioned that they used mathematics whenever they went shopping.

With the exception of the Kero pupils, few of the Community School pupils appeared to understand the mechanism by which grade 6 leavers are selected to go on to high school. Many gave the impression that they felt the selection was arbitrary, done by teachers or the government; few seemed to think that selection was related to performance on examinations. The view that one is not personally responsible for one's own examination results, and that to work towards selection is rather pointless, was common among Community School children. It was not surprising, therefore, to find that very few Community School pupils looked forward to going to high school, or to jobs which required further education. National pupils at the International Primary School, however, were usually confident that they would proceed to high school and to jobs which required a high school background.

5. DISCUSSION

It should be noted that all comparisons between groups were done on the basis of grade levels rather than chronological age. In general, for any particular grade level, Community School pupils tended to be a year or two older than their International Primary School counterparts.

The results which have been presented indicate that the tasks may be regarded as falling into two categories: those for which the results of the

Community School pupils were similar to those of International Primary School pupils, and those for which the results for these two groups were markedly different. Included in the first category are the memory tasks and most items on the Mathematics Test (including estimation and conservation tasks). The second category contains several spatial tasks ('fitting shapes', the Deregowski-inspired drawing-to-model and photograph-to-model tasks, and the co-ordination of perspectives task) and the group tests, PMAT, MAMP and the Mathematical Language Test.

5.1 MEMORY TASKS

The results of the visual memory tasks utilizing 2 x 3 and 3 x 4 arrays of objects and symbols indicate that if, as Bishop conjectured, visual memory is a strength of PNG children then it is also a strength of Expatriate children. Our results contrast with those of Kearins (1976), who found that Aboriginal children did significantly better than white children on certain visual memory tasks; in our case we found the performances of National and Expatriate children to be fairly similar, with the Expatriate children doing slightly better. Further, the fact that the Wonenara children, who were the oldest and least acculturated of those in our sample, performed less well than younger, more acculturated children on the matrix-array visual memory tasks, suggests that Bishop's conjecture that less acculturated children have better visual memories than more acculturated children is false.

Our investigations also tended to disconfirm the spirit of Bishop's conjecture that memory tasks are performed by PNG students with little or no verbal mediation. Certainly, National students made little use of verbal coding when attempting the matrix array tasks requiring memory of positions of objects; however, the same could be said of Expatriate subjects attempting the same tasks. Also, both National and Expatriate subjects invariably used a verbal coding procedure when attempting matrix array tasks requiring memory of positions of numerals. Similarly, many National and Expatriate subjects reported that they invented names for 'nonsense symbols' when attempting the matrix 'nonsense symbols' task. Thus it would appear to be the case that the cognitive strategies used on the matrix memory tasks depended more on the stimuli whose positions had to be remembered than on variables concerned with race and culture.

Another interesting feature of the matrix visual memory results was that all subgroups did best on those tasks for which objects were

the stimuli, and most subgroups had greatest difficulty in remembering the positions of numerals; tasks with 'nonsense symbols' as stimuli were, in most cases, of intermediate difficulty. The order of difficulty of tasks tended to be the same for both National and Expatriate subjects. Since, as previously mentioned, subjects did not appear to make use of verbal coding when attempting to remember positions of objects, but did make use of verbal coding when attempting to remember positions of numerals, our results do not support the popular view that verbal coding enhances memory (see Swanson, 1978).

The matrix array tasks were not the only memory tasks on which the various subgroups involved in our investigation used similar processing modes and performed at about the same level. Indeed, over the whole range of memory tasks the pattern and level of performance for Community School children in different PNG Provinces, for National children attending the International Primary School, and for Expatriate children attending the International Primary School, were similar. In particular, the relative difficulties of tasks in a battery of digit span tests in which various modes of presentation were employed (simultaneous visual, sequential visual, auditory forwards, auditory backwards), varied very little from subgroup to subgroup. The pattern of results on these tasks followed that found by Torgesen et al. (1978) with a sample of American children. Our findings provide support, therefore, for Cole and Scribner's (1974) position that 'we are unlikely to find cultural differences in basic cognitive processes'.

It is likely, however, that Community School pupils make greater use of their visual memories than International Primary School pupils when attempting to memorize knowledge and master intellectual skills and concepts. If, as our results indicate, Community School children in the lower grades have difficulty understanding the English spoken by their teachers it is reasonable to hypothesize that they would find it easier to comprehend and remember information which is presented to them visually. The reliance on visual memory might be expected to decrease as English language competence increases in higher grades. With this conjecture in mind it is interesting to observe Pearson product-moment correlation co-efficients between performances on the PMAT test and visual memory 3 x 4 matrix array tasks calculated for grade 2, 4 and 6 pupils at Kero Community School. The sample comprised twenty grade 2 pupils, ten grade 4 and ten grade 6 pupils, and the PMAT/visual memory correlations were 0.72, 0.39 and 0.20 for grades 2, 4, 6 respectively. Dr Randall Souviney, Director of I.M.P., has also

calculated PMAT/visual memory correlations for a much larger sample of PNG children in grades 2, 4, 6 at five Community Schools, and has obtained similar results. The correlation co-efficient he obtained for the grade 2 children was much higher than that for the grade 6 level (Souviney to Clements & Lean, personal communication, 1980). With respect to these results it is probably relevant to point out that it is likely that teachers of grade 2 children throughout the world tend to rely more on visual aids when teaching mathematics than do teachers of children in grades 4 and 6.

Another conjecture relating to visual memory will be noted here. It is possible that what we have called 'visual memory' is what Jaensch (1930) termed 'labile eidetic imagery', which, according to Jaensch, is normally common in young children but tends to fade in adolescence as language and coding competence increases. While this may be the case for schoolchildren whose first language is the same as the language of instruction, in Papua New Guinea visual memory (or 'labile eidetic imagery') may continue to be important in higher grades. Bishop (1978(a)) found, for example, that PNG university students had strong visual memories. Data from high school subjects would be useful for investigating this conjecture. If the conjecture were found to be true then the visual memory variable would need to be taken more seriously by all persons involved in the development, for PNG educational institutions, of curricula and associated teaching and learning materials.

5.2 THE MATHEMATICS TEST

The performances of Community School and International Primary School children, at corresponding grade levels, were similar on most but not all, tasks on the Mathematics Test. Neither group was clearly superior to the other on everyday tasks requiring counting, addition, subtraction, multiplication and estimation; however, on tasks requiring division and understanding of fractional concepts International Primary School children did better. Performances on conservation tasks were similar provided grade level, not age, is taken as the basis for comparison. The Results on the conservation tasks were not inconsistent with those reported by Shea (1978(b)).

For most tasks on the Mathematics Test International Primary School children and Community School children tended to employ similar mental processing procedures; this was not true, however, for questions involving

division or understanding of fractional concepts. Most Community School children did not appear to be able to formulate appropriate strategies for solving such problems. It is likely that Community School children experience difficulty in solving 'division' and 'fraction' problems because they cannot understand explanations of relevant concepts which are given to them by their teachers. None of the tok ples languages of the children we tested contained a word for the rational number 'one-third', for example, and there was no generalized expression for the operation of 'taking one-third of' something. Thus the following question, which would have meaning to most International Primary School children from grade 4 onwards, could not be translated into the tok ples of Community School children.

> Here are six buai. If you gave me one-third of them, how many would you give me?

Such a question would have to be rephrased if it were to be made meaningful for most Community School children. It is likely that something similar to the following supposedly equivalent question would be provided.

> Here are six buai. Suppose you gave them to Jack, Luke and Kuni so that each got the same number of buai. How many would each get?

While the above two questions have the same answer the former is more difficult because it involves the generalized concept of 'one-third of', whereas the latter avoids this. Community School teachers could hardly be expected to be aware of such a subtle difference. And even if they were, it is not easy to specify pedagogical procedures which will overcome the difficulty. The teacher who attempts to bring Community School children to an understanding of the generalized concept of 'one-third of' is faced with the task of using English, which is perhaps the third or fourth language of the children (and often of the teacher, also), to explain something which has no direct equivalent in the tok ples of the children. If the teacher prefers to avoid the difficulty by rephrasing questions so that the generalized concept is not involved, then the children are not likely to develop an understanding of the generalized concept (a concept which, incidentally, is expected of children in Provincial High Schools).

Further discussion of the influence of language on performances of Community School children will be given shortly, in the section concerning the pencil-and-paper group tests.

5.3 SPATIAL TASKS

Most Community School children did not do as well as National or Expatriate children in the same grades at the International Primary School on the following spatial tasks: 'fitting shapes', the Deregowski drawing-to-model and photograph-to-model tasks, and the co-ordination of perspectives task. The superior performance of International Primary School children on these tasks can almost certainly be attributed to the fact that while the concepts and knowledge of spatial conventions which were demanded are often associated with experiences which International Primary School children receive at home or school, this is not the case for Community School children. The 'fitting shapes' task, or a variant of it, is commonly found in kindergartens and pre-school centres, for example, and every day International Primary School children see pictures and photographs. By contrast, some of our Wonenara subjects had never drawn a picture, and there were no books or photographs in their homes. The 'fitting shapes' task was a completely new and confusing experience for them. It need hardly be added that few of them had had the opportunity to play with educational toys or see movies, slides and videotapes.

National subjects performed as well as International Primary School subjects, however, on the Hughes Perspective task and almost as well as them on all memory tasks which involved visual imagery (including Memory-for-Designs, and two and three-dimensional visual memory tasks).

From our point of view it appears that if group differences between spatial abilities of National and Expatriate children exist they are small, and are certainly much less than within-group differences. Indeed, we would put forward the conjecture that there are no between-group differences, and would maintain that differences in spatial performances found in the present study represent the cumulative effects of background influences, especially home and school experiences, which gave International Primary School children a better preparation than the Community School children for most of the spatial tasks which we used.

5.4 MEMORY SPACE

At each of grades 2, 4, 6 the mean memory-space score of National subjects attending Community Schools was slightly below corresponding mean scores of both National and Expatriate subjects attending the International

Primary School. Rather than interpret this as evidence for Community School children having less 'ability' than International Primary School children we are inclined to the view that the task, which involved perception and memorization of details associated with line drawings, was culturally biased in favour of those who had been brought up in a Western environment.

5.5 THE GROUP TESTS

The means of Community School subjects were considerably below those of International Primary School subjects at the same grade levels on each of the three pencil-and-paper group tests, PMAT, MAMP, and the Mathematical Language Test. We would maintain that the between-group differences in performances on these group tests are largely explicable in terms of the different language backgrounds of the children; in particular, many Community School children simply did not understand the meaning of most of the questions on the tests. And while it is apparently unfair to compare performances of children whose native language is English (the majority of International Primary School subjects) with those for which English is the third or fourth language (Community School subjects) it must be remembered that English is the medium of instruction in Community Schools, and English is the language used in text books and written examinations set by the Papua New Guinea Department of Education. Undoubtedly, lack of comprehension of mathematical language seriously disadvantages many Community School children in mathematics classrooms.

Results on the Mathematics Language Test provide the most obvious support for the above view. Questions on this test did not involve difficult calculations, and it appears reasonable to maintain that the test primarily involves comprehension of mathematical language. Jones' analysis indicates that on this test National children at both Community and Provincial High Schools typically perform at a level which is about four grades below that of Expatriate children, and two grades below National children, attending the International Primary School.

It was previously noted that Community School children performed relatively well on word-free computational problems, but had great difficulty with verbal arithmetic problems, on PMAT and MAMP. This raises the question of whether Community School graduates will be able to solve everyday problems requiring simple calculations. The ability to carry out basic calculations accurately can be quite useless unless it is accompanied by the ability to comprehend and interpret situations for which the calculations are appropriate.

Another factor which helps to explain the relatively poor performance of Community School children on the verbal arithmetic problems on the group tests is the emphasis which Community School teachers put on basic numerical competence to the detriment of other aspects of mathematics. As noted earlier, interviews with Community school children revealed that they viewed mathematics as nothing more than 'sums'. Recent reports claiming that number skills 'have fallen to an unacceptably low level' (Roberts, 1978, p.215) might persuade teachers and teacher-trainers to pay even less attention to helping children read and understand mathematical language, and to whether they can devise appropriate strategies for solving problems.

6. CONCLUSIONS

In this study we found no educationally significant differences in performances of National and Expatriate children at the same grade levels in Papua New Guinea on memory tasks, and on certain mathematical and Piagetian conservation tasks (which were presented to children in their first languages if they had difficulty understanding English or tok pisin). There were marked differences, however, in the performances of National and Expatriate children on pencil-and-paper group tests of mathematics and mathematical language, and on certain spatial tasks.

It has been argued that whenever large group differences did occur these could be more easily explained in terms of cumulative socialization effects than in terms of any basic cognitive differences. Thus, because National children have not grown up in environments in which line drawings, photographs or audio-visual experiences are commonplace, they are disadvantaged, in comparison with Expatriate children, if asked to perform tasks which involve recognition and interpretation of features in line drawings, photographs, and audio-visual presentations. If it is deemed to be desirable that National children develop skills necessary to perform such tasks as well as Expatriate children (and that should not be taken for granted), then research is needed to determine which remedial experiences should be provided in Community Schools in order that desired improvements will be most speedily and effectively achieved.

It is apparent from the study that difficulties experienced by Community School children in understanding English, and especially mathematical English, are important in explaining why many National children cannot solve elementary verbal arithmetic problems. Research aimed at

identifying important changes in mathematics curricula for Community Schools, and developing pre-service and in-service programs which make Community School teachers more aware of, and competent to deal with, the special problems associated with comprehension of mathematical language, is needed. Any proposed changes should take account of the fact that, unlike children attending primary schools in western countries, Community School children do not belong to social environments which reinforce those mathematical skills, concepts and problem solving procedures which comprise the greater part of mathematics syllabuses prescribed for Papua New Guinean Community Schools. Also, it needs to be remembered that many mathematics teachers in the Community Schools are, themselves, neither mathematically competent nor confident, and are content to encourage pupils to do little more, in mathematics lessons, than to learn number facts and formulae by heart, and to apply algorithms in the most mechanical fashion.

Compared with, say, primary mathematics courses in most Australian states, the MaCS syllabus is relatively sophisticated and ambitious; it would hardly be surprising if even experienced teachers found difficulty in implementing it effectively. The needs of mathematics education in Papua New Guinea would, perhaps, be better served by syllabuses which took more account of the immediate backgrounds of pupils and teachers, and were pitched at levels at which the pupils really <u>are</u>, rather than at those levels which curriculum planners believe they <u>ought to have</u> reached.

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APPENDICES

Three appendices are given:

A. Experimental Results Sheet (used for recording results during testing of individuals in the 'Interview' sample).

B. The Mathematical Language Test, developed by P.L. Jones, 1980.

C. The 'Interview Schedule', used with the 'Interview' sample.

APPENDIX A: Experimental Results Sheet

LOCATION: _____ SUBJECT [ ]

DATE: _____

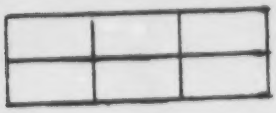
NAME: _____ AGE: _____

GRADE: _____ TEST LANGUAGE: _____

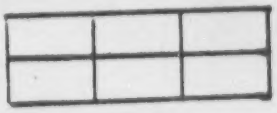
TIME TAKEN: _____

1. VISUAL MEMORY

a) 2 × 3 Familiar



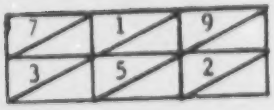
b) 2 × 3 Unfamiliar



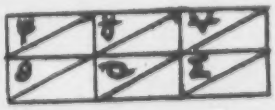
c) 3 × 4 Familiar

d) 3 × 4 Unfamiliar

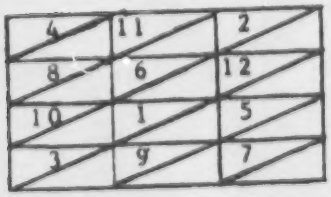
e) 2 × 3 Numbers



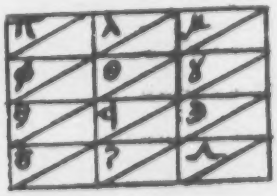
f) 2 × 3 Symbols



g) 3 × 4 Numbers

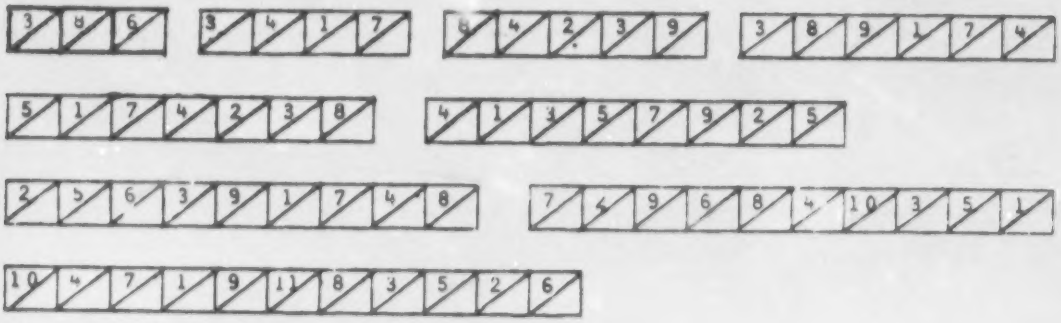


h) 3 × 4 Symbols



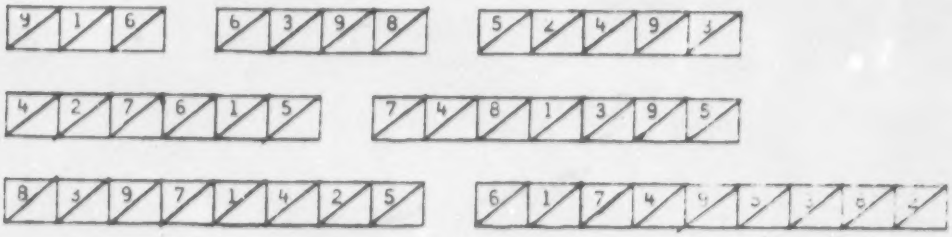
APPENDIX A (contd.)

i) Simultaneous linear Visual digit span



j) 2 x 3 Spoken Numbers :

k) Sequential linear Visual digit span.



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2. Mathematics Test

1. Count 1 - 25. _____
2. 3 + 5 = _____
3. 70t - 40t = _____
4. 4 x 3 = _____
5. 12 ÷ 3 = _____
6. 50t + 20t = _____
7. K1 - 60t = _____
8. ½ of 6 stones = _____
9. 1/3 of 6 stones = _____
10. ½ of sugar cane = _____
11. 1/3 of sugar cane = _____
12. Conservation of Number

    Q1. _____

    Q2. _____

    Why ? _____

13. Conservation of Length.

Q1: _____
Q2: _____
Why ?: _____
Q3: _____
Why ?: _____

14. Conservation of Substance.

A. Q1: _____
Q2: _____
Why ?: _____
B. Q1: _____
Q2: _____
Why ?: _____

15. Estimation: stones : _____

16. Estimation: water : _____

17. Matchstick shapes : _____

18. Measurement : _____

19. Template : _____

20. 7 × 7 patterns

a) cross _____ b) F _____
c) point _____ d) diagonal _____

3. DIGIT SPAN

Digits forward : Score

3: 3-8-6 _____
4: 3-4-1-7 _____
5: 8-4-2-3-9 _____
6: 3-8-9-1-7-4 _____
7: 5-1-7-4-2-3-8 _____

6-1-2 _____
6-1-5-8 _____
5-2-1-8-6 _____
7-9-6-4-8-3 _____
9-8-5-2-1-6-3 _____

Digits Backward. Score

Trial : 9-2-7 (if correct proceed to 3-digit series).

2: 2-5 _____ 6-3 _____

3: 5-7-4 _____ 2-5-9 _____

4: 7-2-9-6 _____ 8-4-9-3 _____

5: 4-1-3-5-7 _____ 9-7-8-5-2 _____

6: 1-6-5-2-9-8 _____ 3-6-7-1-9-4 _____

7: 8-5-9-2-3-4-2 _____ 4-5-7-9-2-8-1 _____

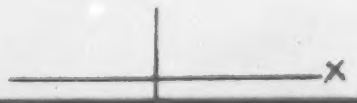
Total digit span

4. Fitting shapes

5. Hughes' Perspective Task.

a)

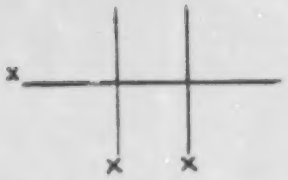
b)

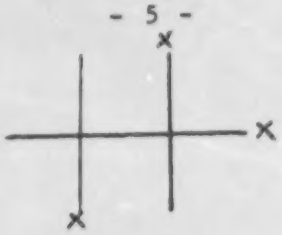
c) 

d)

APPENDIX A: Experimental Results Sheet (contd.)

- 5 -

f) 

(f) 

6. Deregowski Models (from diagrams)

a)

b)

c)

d)

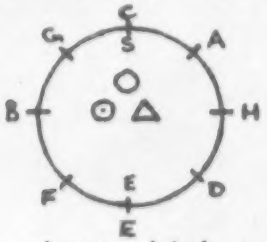
e)

7. 3 - D Visual Memory

8. Deregowski Models (from photos)

9. Coordination of Perspectives.

G B F H E A D C (photos in order)



Q1. Pick the photo which was taken from where you are sitting. _____ (C)

Q2. Pick the photo taken from where I am sitting. _____ (E)

Q3. Pick the photo taken from here (Point to position A) _____ (A)

Q4. Pick the photo taken from here. (Point to position D) _____ (D)

Q5. Where was this photo t en from? (Point to photo G) _____ (G)

Q6. Where was this photo taken from? (Point to photo B). _____ (B)

Q7. Where was this photo taken from? (Point to photo F) _____ (F)

Q8. Where was this photo taken from? (Point to photo H)

APPENDIX A: Experimental Results
Sheet (contd.)

MEMORY-FOR-DESIGN

1.

2.

3.

4.

5.

6.

7.

8.

9.

10.

11.

12.

13.

14.

15.

APPENDIX B: Mathematical Language Test

NAME:
AGE :
SEX :
SCHOOL:

LANGUAGE AND MATHS (10 Minutes)

1. Which is more, 10 or 13?
   Answer:

2. Which number is 1 more than 5?
   Answer:

3. John has 5 fish and Bill has 7 fish. Who has more fish?
   Answer:

4. Patrick has 2 more fish than Christopher. If Patrick has 8 fish, how many fish does Christopher have?
   Andwer:

5. The number 8 is 2 more than what number?
   Answer:

6. What is 3 more than 6?
   Answer:

7. Which is less, 7 or 9?
   Answer:

8. Which number is 2 less than 5:
   Answer:

9. Mary has 7 shells and Margaret has 3 shells. Who has less shells?
   Answer:

10. Anne has 3 less shells than Gertrude. If Anne has 5 shells, how many shells does Gertrude have?
    Answer:

11. The number 6 is 2 less than what number?
    Answer:

12. What is 3 less than 5?
    Answer:

13. My pencil is 8cm long. John's pencil is 2cm shorter than mine. How long is John's pencil?
    Answer:

14. My stick is 15cm long. Bill's stick is 13cm longer than mine. How long is Bill's stick?
    Answer:

15. It is now 2.00 o'clock. What time will it be in 2 hours time?
    Answer:

16. It is now 5.00 o'clock. What time was it 3 hours ago?
    Answer:

17. A trade store is open from 1.00 p.m. to 4.00 p.m. For how many hours is it open?

APPENDIX C

INTERVIEW SCHEDULE

NAME: _____ GRADE : _____

SCHOOL : _____

FAMILY LIFE

How many brothers _____ theif ages ? _____ _____

do you have ? _____ _____ _____

How many sisters do their ages ? _____ _____

you have ? _____

What job does dad have ?

What does mum do ?

What are your favourite hobbies ? _____

Do you get any pocket money ? _____

What do you often do after school ? _____

_____

at weekends ? _____

_____

How often do you do homework ? _____ who helps you ?

_____ Do you read many books ? _____

Do you do much maths homework ? _____

Who helps you with that ? _____

A Typical Day in the Life of _____

Schoolday

Saturday

MATHEMATICS

When you have maths at school, what do you do ?

Does the teacher write the problems in the B/B, or do you do problems from a book ?

Can you remember using the mathematics you've learnt at school at home ?

- when you're shopping down the street ?
- anywhere else ?

Do you like Maths as much as your other subjects ?

AMBITIONS

When you grow up what job would you like to do ?

How old do you think you'll be when you leave school ?

What job do you think mum and dad would like you to have when you get older ?

INDIGENOUS MATHEMATICS PROJECT

WORKING PAPER SERIES

1. Learning to Compute.
   R. Souviney, January 1980.

2. Strategies for Mathematical Problem Solving.
   R. Souviney, March 1980.

3. Assessment Administration Guide.
   R. Souviney, April 1980.

4. Field Guide for Studying Classroom Events and Their Cultural Context.
   P. Levin, M. Gearhart and R. Souviney, June 1980.

5. International Congress on Mathematics Education.
   R. Souviney, V. Kada and D. Malaga; D. Lancy; M. Britt; B. Roberts, August 1980.

6. Andra Community School Field Report.
   P. Levin, November 1980.

7. Ororo Community School Field Report.
   J. Lineberger, November 1980.

8. Divanap Community School Field Report.
   M. Gearhart, November 1980.

9. Kero Community School Field Report.
   K. Johnson, November 1980.

10. Muglamp Community School Field Report.
    B. Rowe, November 1980.

11. Teachers Notes and Student Worksheets – Grade 2. 1980.

12. Teachers Notes and Student Worksheets – Grade 4. 1980.

13. Teachers and Students Text – Grade 6. 1980.

14. The Changing Form of Numerical Reasoning Among the Oksapmin.
    G. Saxe, January 1981.

15. Intra-Cultural Variation in Cognitive Development – Conservation of Length Among the Imbonggu.
    D. Lancy, R. Souviney, V. Kada, February 1981.

16. The Education of Atawe.
    M. Clements and P. Jones, March 1981.

17. Influences on Mathematical Learning in Papua New Guinea – Some Crosscultural Perspectives.
    M. Clements and G. Lean, May 1981.

18. Teaching Community School Mathematics – A Comparison of Five Sites.
    B. Miller-Souviney, June 1981.

19. Classroom Maths Games.
    IMP Staff, June 1981.

20. Teaching and Learning Mathematics in the Community Schools of Papua New Guinea.
    R. Souviney, July 1981.